628.

JOURNAL

OF THE

New England Water Works

ASSOCIATION.

VOLUME XI.

September, 1896, to June, 1897

PUBLISHED BY

BOARD OF EDITORS.

Junior Editor's Office, New London, Conn.

INDEX.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

VOL. XI. SEPTEMBER, 1896. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME OBSERVATIONS ON THE RELATION OF LIGHT TO THE GROWTH OF DIATOMS.

BY GEORGE C. WHIPPLE.

[*Read June* 11, 1896.]

In a paper published in 1894, the writer suggested an explanation for the peculiar seasonal distribution of diatoms in lakes and ponds. It was shown that in deep ponds these minute plants are usually found abundantly during the spring and fall, but are almost entirely absent during the summer and winter; that these growths are closely connected with the phenomena of circulation and stagnation of the water, which phenomena are due to temperate changes; and that it is during the periods of the year when the water is in complete circulation throughout the vertical, that the diatom growths occur. The explanation offered for these facts had reference chiefly to the food supply. It was stated that diatoms require a sufficient supply of nitrogen in the form of nitrates, and that they require a free circulation of air; and it was shown how during the "periods of circulation" in the spring and fall these conditions were fulfilled. In the light of more extended observations and experiments this food supply theory, taken alone, is seen to be inadequate, and while it is true that the question of food is one of fundamental importance, yet there are other factors which materially influence their growth. With a view to determining the nature and effect of some of these influences, the writer has conducted during the past year several series of experiments, some of the results of which are here presented.

It is not an easy matter to cultivate diatoms successfully in the laboratory to obtain comparative results. They are organisms which have an extremely sensitive nature, and slight changes in their environment often make great differences in their growth. The temperature, the amount of light, the shape and size of the jar in which they are grown, the action of the glass upon the water, etc., are all disturbing elements affecting their growth. Take, for example, the shape of the jar. On one occasion three portions of a sample of Cochituate water were placed in three jars of various shapes, each of which held 500 cc. In the first, the water had a depth of 25 cm. and a surface area of 20 sq. cm.; in the second the depth was 7.1 cm. and the area 70 sq. cm.; in the third the depth was 2.7 cm. and the area 186 sq. cm. The three jars were placed side by side on the window sill, so that they received practically the same amount of light, and the temperature was found by observation to be the same in each case. The water in each jar originally contained 226 diatoms per cc. After standing ten days the water in the first jar contained 685 per cc.; in the second jar, 1,537; and in the third jar, 7,585. Of the last 6,060 were Synedra, 1,080 Melosira, 235 Tabellaria, 200 Asterionella, 10 Stephanodiscus.

The large number per cc. in the third jar was no doubt partly caused by greater evaporation from the large surface exposed and the consequent higher concentration of the organisms, but it was chiefly due to the greater opportunity for the absorption of air. In the deep jar the water could not take up the oxygen and carbonic acid from the air as fast as the diatoms used them up. Moreover the diatoms settled to the bottom of the jars, where they grew as a brown, velvety layer. The distance of these growths from the surface also affected their supply of air.

Another experiment made at the same time gave similar results. Into three cylinders, equal in diameter, were poured different quantities of the same sample of water. The first contained 100 cc., the second 200 cc., and the third 500 cc., the depths being, respectively, 1.4 cm., 2.9 cm., and 7.1 cm. The original water contained 226 diatoms per cc. After ten days the first jar contained 2,288, the second 1,733, and the third 1,537 per cc.

To more clearly illustrate the fact that diatoms do not grow without air, two cultures of reservoir water were made in flasks, one being open to the air and the other covered with a thin layer of oil. The

water originally contained 150 per cc. After twenty-five days the open flask contained 7,648 per cc., while the other contained but 192. An attempt to force a growth of diatoms in a flask by allowing air to continually bubble up through the water was a failure, the agitation produced being more than the delicate plants could stand.

It was also found in the laboratory experiments that the position of the jars in the window caused marked variations in the intensity of the growths. Those on the side of the window where the light was strongest gave the heaviest growths, except in one spot where the sunlight fell; there the growth was small. These facts led to a more extensive investigation to determine the effect of light of varying intensities. It was known, of course, that, in common with all chlorophyllaceous plants, diatoms will not grow in the dark, and it was also known that exposure to bright sunlight will kill them, but between the bright sunlight and total darkness there was a wide field for experiment.

A variety of preliminary experiments was made to determine the best method of regulating the intensity of the light and of securing such conditions that the results would be fairly comparable. They all showed that in the laboratory it was next to impossible to secure the desired result. It was therefore decided to make the experiments in the ponds themselves, under conditions as nearly as possible like those found in nature.

The method employed was an extremely simple one. It consisted of suspending bottles filled with water from the same source at different depths in the pond, the bottles being tied to a rope which hung from an anchored buoy. After a certain time the bottles were drawn to the surface and the water examined, records being kept of the number of diatoms in each sample before and after exposure. The bottles varied in capacity from 150 to 1,000 cc. In the first five experiments they were tightly stoppered, but in the later ones silk bolting cloth was tied over the mouths of the bottles, and inverted glass tumblers were placed above. The latter arrangement gave much heavier growths on account of providing better opportunity for the circulation of air and for the renewal of food supply.

The results of the experiments are given in tabular form at the end of this paper. Before discussing them, however, it will be appropriate to consider the subject of the nature and intensity of the light at various depths in the water.

This subject has not been as thoroughly investigated as its importance appears to demand, and most of the investigations that have been made were made upon the clear water of the ocean or of large lakes. Perhaps the most complete study of the transparency of water was that made by Prof. F. A. Forel upon the water of Lake Leman in Switzerland.

His experiments are fully described in the second volume of his recentmono graph, entitled, "Le Léman."* Three methods of experiment were employed. The first was that of the visibility of plates. This method, first used by Secchi in 1865 in determining the transparency of the water of the Mediterranean Sea, consisted of lowering a white disk (20 cm. in diameter) into the water and noting the depth at which it disappeared from view, and then raising it and noting the point at which it reappeared. The mean of these two depths was called the limit of visibility. The second method, known as that of the Genevan Commission, was similar to the first, but instead of a white disk an incandescent light was lowered into the water. This light when seen through the water from above presented an appearance similar to that of a street lamp in a fog, that is, there was a bright spot surrounded by a halo of diffused light. When the light was lowered into the water this bright spot first disappeared from view. The depth of this point was noted as the "limit of clear vision." Finally the diffused light disappeared, and the depth of this point was noted as the "limit of diffused light." Both the first and second methods were useful only in comparing the relative transparency of different waters or of the same water at different times. In order to get an idea of the intensity of light at different depths a photographic method was used. Sheets of sensitized albumen paper were prepared and mounted in a frame in such a way that half of the sheet was covered with a black screen, while the other half was exposed. A series of these papers was attached to a rope and lowered into the water; they were at equal distances apart, and so supported that they assumed a horizontal position in the water. They were placed in position during the night and allowed to remain twenty-four hours. On the next night they were drawn up and placed in a toning bath. A comparison of the prints made at different depths enabled the observer to determine the depth at which the

* F. A. Forel, "Le Léman," monographie limnologique, Lausanne, 1895.

light ceased to affect the plates and to obtain some idea of the relative intensity of the light at the different depths. To assist in this comparison an arbitrary scale was made by exposing sheets of the same paper to bright sunlight for different lengths of time.

The results of the experiments are given by Forel as follows: —

In Lake Leman the limit of visibility of a white disk 20 cm. in diameter was 21 m. The limit of clear vision of a 7-candle-power incandescent lamp was 40 m.; the limit of diffused light was about 90 m. The depth at which the light ceased to have any effect on the photographic paper was 100 m. when the paper was sensitized with chloride of silver, and about 200 when sensitized with iodobromide of silver. These depths were much less in summer than in winter on account of the increased turbidity of the water. The transparency of the water of other lakes, as shown by the limit of visibility of a white disk, is cited as follows: Lake Tahoe, 33 m.; La Mer des Antilles, 50 m.; Lac Lucal, 60 m.; Mediterranean Sea, 42.5 m.; Pacific Ocean, 59 m. It should be remembered that these are all comparatively light-colored waters, and that in them the light penetrates to far greater distances than in many of our brown-colored New England ponds. For example, in the Chestnut Hill Reservoir a plate lowered into the water at a time when the color was 0.92 disappeared from view at a depth of only six feet.*

The decrease in the intensity of light below the surface is due to two causes: First, the absorption of a certain portion of the light by the water; and second, the presence of fine particles in suspension, which act as a screen to shut out the light. The coefficient of absorption of light by water is practically unknown. It varies greatly, of course, with the quality of the water. Wild† gives the following figures for distilled water, and shows that the power of absorption increases with the temperature:

---

*Recent experiments by the writer have shown that the limit of visibility may be determined most accurately by using a disk about eight inches in diameter divided into quadrants painted alternately black and white like the target of a level rod; and looking vertically down upon it through a water telescope provided with a suitable sunshade. It has been found that the limit of visibility obtained in this manner bears a very close relation to the turbidity of the water, and it seems quite possible that this simple experiment may be of considerable value in determining the relative turbidities of different waters.

†H. Wild: Ueber die Lichtabsorption der Luft. Poggendorf's Annalen, Anhang cxxxiv, 582, Berlin, 1868.

Temperature.	Intensity of light after passing through 1 dm. of distilled water.*
24.4° Cent.	0.9179
17.0° "	0.93968
6.2° "	0.94769

The reduction of light in passing through water is supposed to follow the law that as the depth increases arithmetically the intensity of the light decreases geometrically. For example, if the intensity of the light falling upon the surface of a pond is represented by 1, and if $\frac{1}{4}$ of the light is absorbed by the first foot of water, then the intensity of light at the depth of one foot will be $\frac{3}{4}$; the second foot of water will absorb $\frac{1}{4}$ of $\frac{3}{4}$; and the intensity at a depth of 2 feet will therefore be $\frac{9}{16}$, and so on. At this rate of decrease the intensity of light at a depth of 10 feet will be only about 5 per cent of that at the surface.

In regard to the quality of the light at different depths there is little accurate data to be obtained. In a general way, however, it may be said that the red and yellow rays are most readily transmitted.

The practical question to be decided by the experiments was not the exact amount of light necessary for the development of diatoms, but the depth below which they are unable to grow and the difference in the growths at various depths caused by variations in the intensity of the light. The observations here recorded are offered as a partial answer to these questions.

Plate I shows the results of one series of observations. Bottles were filled with Cochituate water and located in Chestnut Hill Reservoir at depths of 2, 4, 6, 8, 10, and 25 feet, where they remained from April 29 to May 13, 1895. During this time the temperature varied from 53° to 62°, and the color of the water in which they were immersed was 0.58 (Platinum Standard). The relative growths at the different depths are shown by the curve, the number of diatoms in the original water being indicated by the broken line. Near the surface, it will be observed, there was a vigorous growth, there being more than 25,000 diatoms per cc. Most of these were Synedra. At

* Forel considers these values too low, and with this the writer concurs.

greater depths the numbers were less, and at the bottom there were fewer than in the original sample. In experiments Nos. 3 to 7 the

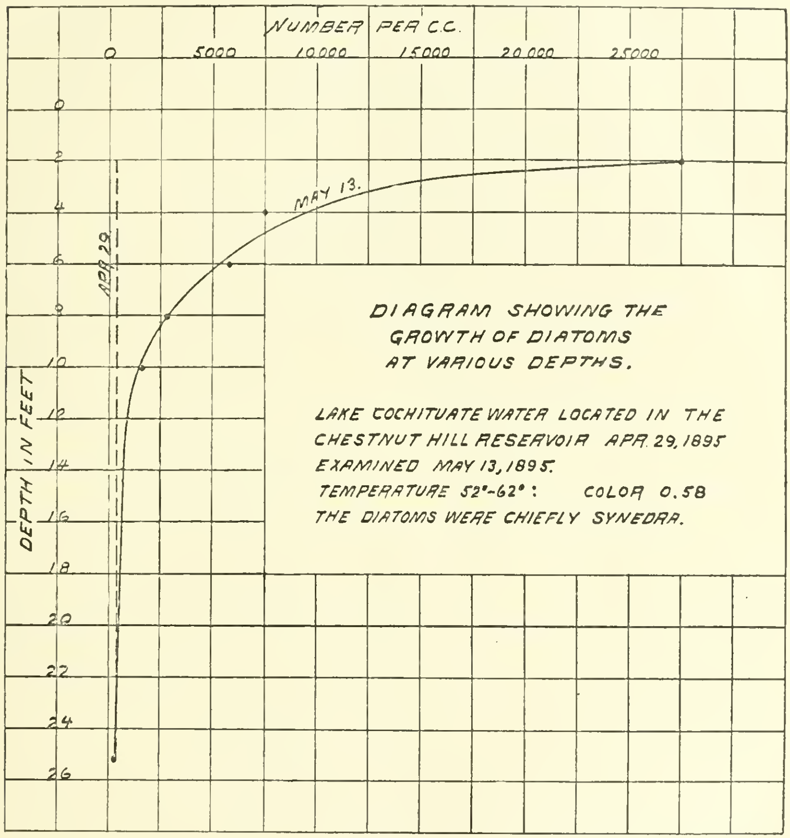


PLATE I.

" surface " samples were so placed that at times they were partially above the water, and therefore exposed to varying atmospheric temperatures and occasionally to direct sunlight. The effect was seen in a diminished growth. In those series the maximum growth was found just below the surface. In the other experiments the "surface" samples were immersed about six inches. These always gave the maximum growths. In Experiment No. 8 there were two "surface"

samples — one just above the surface and one immersed six inches. The latter gave the greater growth.

At what depth do the diatoms cease to develop, that is, at what depth is the intensity of the light so weak that it is incapable of furnishing the energy sufficient for their growth? The experiments show what we should naturally expect, that it depends upon the character of the water — its color, turbidity, etc. This is illustrated by Plate II., which shows the results of two series of experiments upon

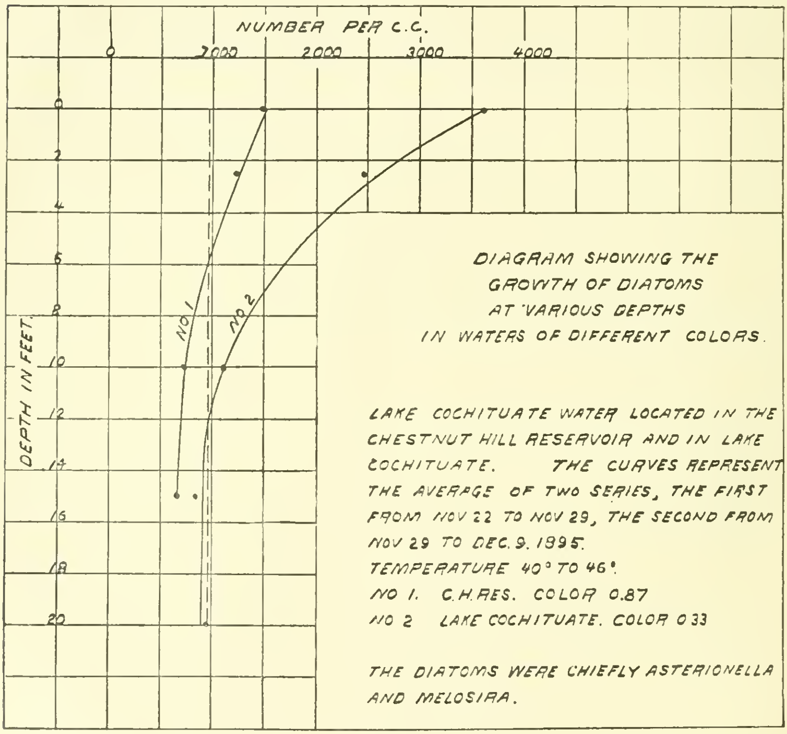


PLATE II.

water of the same kind located in Lake Cochituate and Chestnut Hill Reservoir. The former had a color of 0.33, while the color of the latter was 0.87. The difference between the two series is very striking. In the light-colored water the growths were heavier and extended to greater depths than in the darker water. Curve No. 1

represents the growths in Chestnut Hill Reservoir, and Curve No. 2 those in Lake Cochituate. The number of diatoms in the original sample is shown by the broken line. The point at which this broken line cuts the curves may be called the limit of growth. In Lake Cochituate this point was at a depth of about twelve feet; in Chestnut Hill Reservoir, six feet.

This limit of growth has been determined for each series of experiments. It varies considerably, but may be shown to be dependent largely upon the color of the water. If, for example, we divide the experiments into groups according to the color of the water, we obtain the following average values:

Number of Observations.	Average Color. (Platinum Standard.)	Average Limit of Growth in Feet.
5	0.29	15
5	0.60	12
2	0.86	8

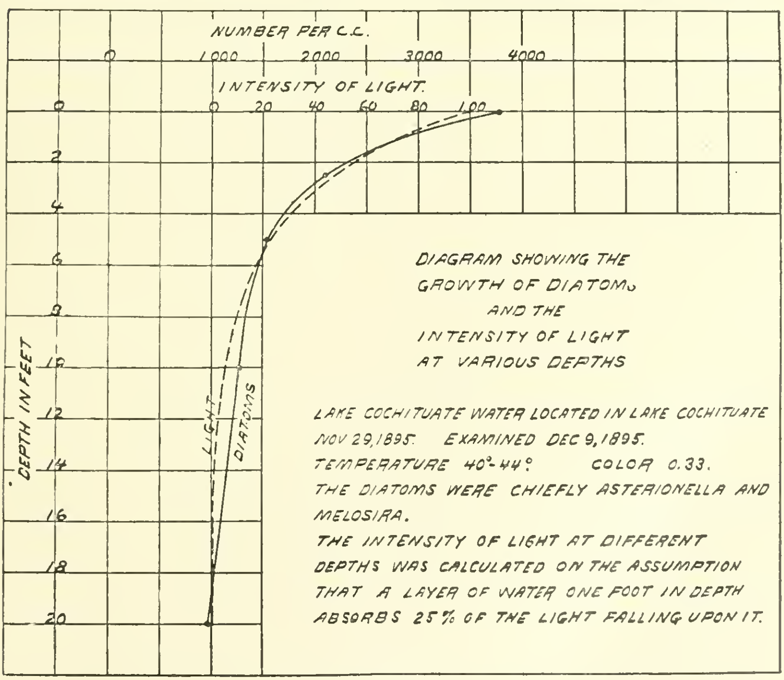


PLATE III.

Thus we see that in the dark waters the limit of growth is about 8 feet, while in the light waters it is about 15 feet. The limit of growth in a perfectly clear, colorless water is unknown, but the experiments of Forel and others indicate that it might be found at a considerable depth.

In order to appreciate better the fact that the extent of the growth of diatoms depends upon the intensity of the light, let us consider Experiments Nos. 9 and 10. These two series of experiments were made at a time when the temperature of the water in the reservoir was almost exactly the same from the surface to the bottom. The average of the results of these two experiments is shown on Plate III. In connection with these experiments the coefficient of absorption of light by the water was approximately determined in the laboratory, and the intensity of light was calculated for the different depths. These values are shown by the broken line on Plate III. The parallelism of this line with that representing the growth of diatoms is very striking.

Plate IV. shows the results of a series of experiments in which several examinations of each sample were made. These emphasize the fact that the rate of growth varies with the amount of light.

In Experiment No. 8 complete microscopical examinations were made. The diatoms, however, were the only organisms that developed extensively. Near the surface a few of the green algæ were seen during the first week or two. The Cyanophyceæ (chiefly a form of Anabæna) increased slightly at first and then began to disappear. Some of the infusoria developed to a slight extent near the surface. Whether this was on account of the difference in the amount of light or in the larger amount of food material near the surface is uncertain. It should be noticed that the amorphous matter increased from week to week, and that it was most abundant near the surface. As a supplement to this experiment, the bottle which had been suspended for three weeks at a depth of twenty feet was brought to the surface on November 30 and supported at a depth of one foot. On December 7 the diatoms, which at the bottom had decreased to 149 per cc., were 278 per cc. and in a healthy condition. They would doubtless have increased still more had not the experiment been accidentally terminated.

Diatoms are said to be positively heliotropic, that is, they tend to move towards the light. In some species this power is quite strong;

in others it is less noticeable. For the purpose of determining the heliotropism of the diatoms commonly found in water supplies,

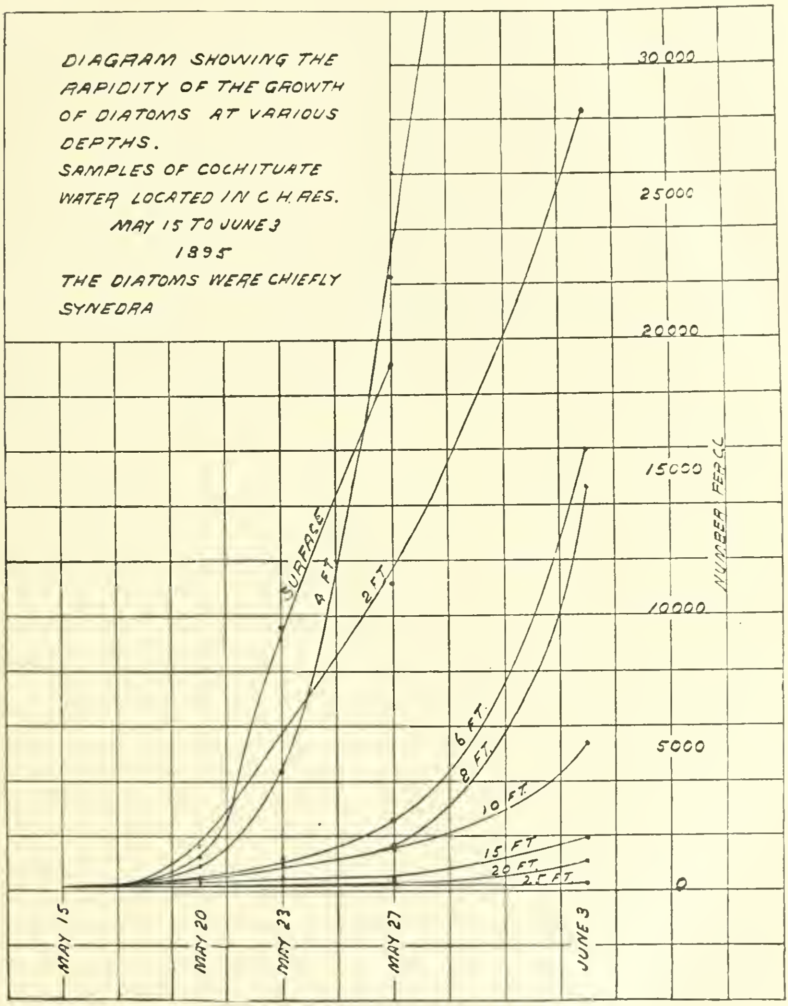


PLATE IV.

samples of water rich in diatoms were placed in brass tubes 3 inches in diameter and 32 inches long, having glass ends. One end was covered with a black cap, and the other end exposed to the light.

After varying lengths of exposure, portions of the water were drawn from each end of the tubes and examined microscopically. As an example of the results obtained the following may be quoted: Cochituate water containing 992 diatoms per cc. was exposed in a tube for twelve hours. At the end of that time the water at the light end of the tube contained 1,438, and that at the dark end only 320. Some of the tubes were inclined, to see if the diatoms would move upwards towards the light; some of them were placed vertical; in others the diatoms were given time to settle before the exposure was made. The experiments showed that most of the common genera tended to move towards the light while settling, but that having once reached the bottom of the tube they remained where they fell. They apparently did not possess the power of moving upwards towards the light — certainly not through any great depth of water. But while they could not rise of their own accord, slight currents of convection caused by varying the temperature of the water sufficed to keep them near the surface.

The inability of certain diatoms to rise towards the light of their own accord was also shown by another experiment. Glass tubes, $1\frac{1}{4}$ inches in diameter and 5 feet long, open at the lower end but closed at the top, were suspended in the reservoir at a time when Tabellaria and Stephanodiscus were numerous. The tops of the tubes were level with the surface of the water, and were so arranged that samples could be drawn from the closed ends. After these tubes were allowed to stand for a few hours it was almost invariably found that the diatoms had settled, and that the water at the top of the tubes was practically free from them. Other experiments along this line are in progress, and it is hoped that some interesting results will be reached.

The bearing which these facts have upon the seasonal distribution of diatoms is obvious, and we are now better able to understand why it is that their growths occur during those seasons of the year when the water is in circulation throughout the vertical. During those periods not only is food more abundant, but the vertical currents keep the diatoms near the surface, where there is light enough to stimulate their growth, and where there is an abundance of air. If this theory be true, it must follow that the weather has a marked influence upon their growth. We should expect that the greatest growths would occur on warm, fair days, when there is just wind enough to keep

the diatoms near the surface. On quiet days we should expect that they would sink in the water, perhaps below the limit of

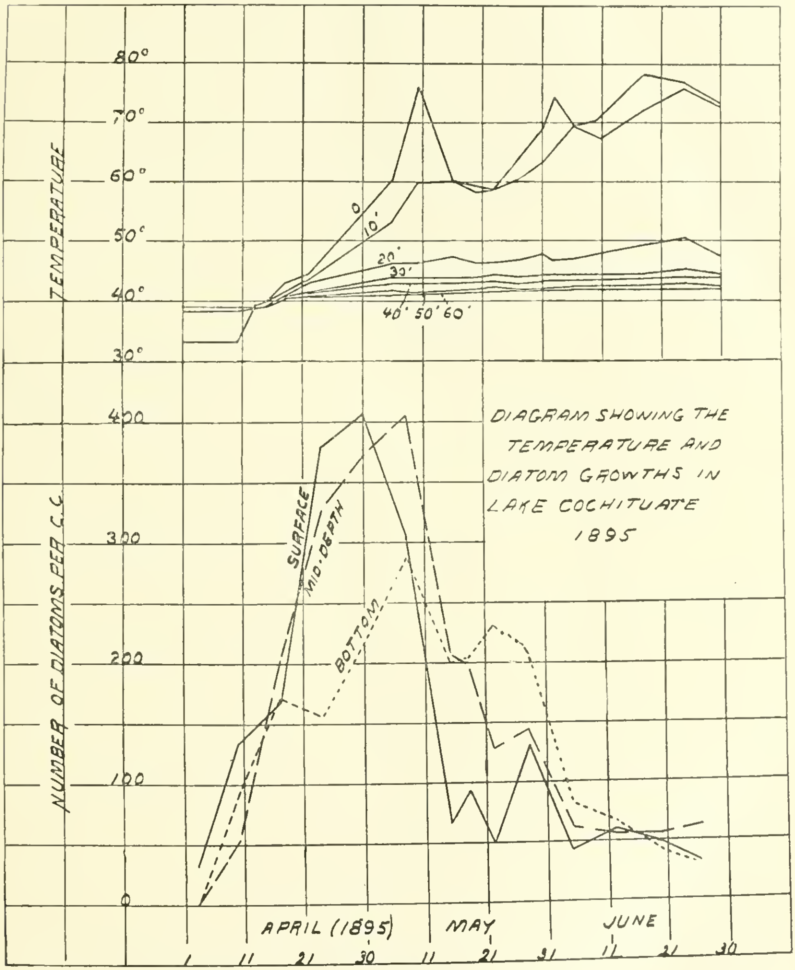


PLATE V.

their growth. During a long period of quiet weather they might sink even to such a depth that they would not again be able to reach the surface.

This is just what took place in Lake Cochituate in the spring o. 1895. In this lake there is almost invariably a heavy spring growth of diatoms, but in 1895 the growth was small. It began as usual, the diatoms being apparently in good condition. Early in May, however, there were a few days of uncommonly warm weather. The temperature of the air went above 90°, and the temperature of the surface water on one day was 76°. For almost a week the water was very calm. During this calm weather the diatoms settled rapidly, disappearing almost entirely from the surface. In the meantime the water became stratified, on account of the high temperature of the surface layers, and when once more the wind began to blow its influence was felt only ten or fifteen feet below the surface. The diatoms, having settled below that depth, were unable to rise, and consequently their growth ceased. These facts are illustrated on Plate V. In Basin III., which is not nearly as deep as Lake Cochituate, the growth of diatoms was arrested during the same warm, quiet period, but inasmuch as circulation afterwards reached to the bottom the growth began again, and continued until the next warm, quiet period, which occurred in June, checked it. In this connection it will be recalled that when the ice forms over a pond the diatom growths usually cease, though several notable exceptions might be mentioned.

Since the growth of diatoms depends upon the intensity of light, and since this is greater in colorless than in dark-colored waters, we may naturally expect to find the most extensive growth in light-colored waters. While it is true that food supply is quite as important as light for the growth of these organisms, yet it is true that to a certain extent the light-colored waters do show the greatest tendency to develop diatom growths.

The writer has recently compared the diatom growths in fifty-seven ponds and reservoirs of Massachusetts, as given in the reports of the State Board of Health. The result of this comparison is shown in the following table. From this we see that most of the heaviest growths occur in the light-colored waters, while in the very dark waters there are few. The table also shows that high chlorine, high hardness, and high nitrogen are favorable to their growth. In other words, an abundant food supply and a light-colored water are among their favorable conditions : —

Chemical Analysis. (Parts per 100,000.)		Number of Ponds and Reservoirs in which Diatoms are: Often above 1,000 per cc.	Occasionally above 1,000 per cc.	Usually between 100 and 500 per cc.	Always below 100 per cc.
Color (Nessler Scale.)	0 to 0.30	12	4	9	4
	0.30 to 0.60	6	2	4	0
	0.60 to 1.00	6	1	5	1
	1.00 to —	0	1	1	1
Excess of Chlorine	0	4	2	1	2
	.01 to .03	8	1	8	2
	.04 to .25	8	3	10	2
	.25 to —	4	2	0	0
Hardness	0 to 0.5	2	1	3	3
	0.5 to 1.0	7	4	5	2
	1.0 to 2.0	8	0	10	1
	2.0 to —	7	3	1	0
Nitrogen as Albuminoid Ammonia (In solution.)	0 to .0100	2	0	2	1
	.0100 to .0150	6	1	5	3
	.0150 to .0200	8	6	7	1
	.0200 to —	8	1	5	1
Nitrogen as Free Ammonia	0 to .0010	3	2	5	3
	.0010 to .0030	6	1	10	2
	.0030 to .0100	8	5	4	1
	.0100 to —	7	0	0	0
Nitrogen as Nitrates	0 to .0050	3	3	5	6
	.0050 to .0100	11	3	13	0
	.0100 to .0200	6	1	1	0
	.0200 to —	4	1	0	0

The writer has avoided reference to particular genera, for the reason that the experiments were hardly extensive enough to draw any general conclusions. The fact was noticed, however, that different genera require different amounts of light for their best growth. Melosira, for instance, do not require as much light as Synedra. In experiment No. 2 Melosira were found growing at a depth of ten

feet. In this connection it is interesting to note that Melosira sink in the water more rapidly than many of the common diatoms. It is very seldom, even during a vigorous growth, that they are found more abundant at the surface than at greater depths. It may be that on account of their tendency to sink in the water they have gradually become adapted to their dark environment, and are able to get along with less light than other diatoms. Asterionella, on the other hand, are slow in settling. Even in quiet weather they are found most abundant near the surface. They are known to be slightly motile, and it may be that, when supplied with a flood of light, their power of heliotropism becomes sufficient to overcome the effect of gravity and keep them near the surface.

In most ponds where diatoms flourish different genera come and go in a most irregular manner; they develop one after another, or they all grow at once; sometimes only one genus appears. No theory has as yet been advanced to account for their erratic succession. It is quite possible, however, that the cause may be found to be connected with their motility, their relative specific gravity and their sensitiveness to light.

In conclusion the writer desires to express his obligations to Mr. W. F. Murphy and Mr. C. E. Livermore, who have kindly assisted him in the various experiments.

EXPERIMENT No. 1.

Sudbury Water located in Chestnut Hill Reservoir, April 8-29, 1895.
Temperature, 39°–53° F. Color, 0.56.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Navicula.	Total.
April 8	All depths.	8	0	1	1	8	0	1
April 29	1 ft.	110	0	4	1,896	16	0	2,028
April 29	5 ft.	162	0	2	54	132	2	356
April 29	10 ft.	0	0	0	3	0	0	2
April 29	15 ft.	0	0	0	2	0	0	3
April 29	20 ft.	0	0	0	8	0	0	2
April 29	25 ft.	0	12	0	6	0	0	18

EXPERIMENT No. 2.

Cochituate Water located in Chestnut Hill Reservoir. April 29 to May 13, 1895.
Temperature, 53°–62°. Color, 0.58.

Date.	Depth.	Number per cc.					
		Asterionella.	Melosira.	Stephanodiscus.	Synedra	Tabellaria.	Total.
April 29	All depths.	94	196	3	11	15	319
May 13	2 ft.	4,040	910	20	22,010	550	27,530
May 13	4 ft.	570	80	10	6,800	120	7,580
May 13	6 ft.	380	650	26	4,510	284	5,850
May 13	8 ft.	650	840	26	1,304	100	2,920
May 13	10 ft.	154	1,380	10	80	0	1,624
May 13	25 ft.	16	132	0	88	28	264

EXPERIMENT No. 3.

Cochituate Water located in the Chestnut Hill Reservoir May 15 to June 3, 1895. Temperature, 62°-68°. Color, 0.57.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
May 15.............	All depths.	61	29	12	17	10	0	129
May 20............	Surface.	196	28	12	896	104	0	1.236
May 20.............	2 ft.	108	32	20	1,408	56	0	1,624
May 20........	4 ft.	116	56	36	584	80	0	872
May 20.............	6 ft.	88	20	32	288	28	0	456
May 20.............	8 ft.	56	8	24	136	24	0	248
May 20.............	10 ft.	0	0	36	220	8	0	264
May 20.............	15 ft.	48	24	8	192	28	0	300
May 20.............	20 ft.	16	16	32	204	16	0	284
May 20............	25 ft.	80	36	20	104	0	0	240
May 23.............	Surface.	140	0	40	9,340	80	0	9,600
May 23.............	2 ft.	80	0	80	6,870	0	220	7,250
May 23.............	4 ft.	572	76	48	3,464	204	0	4,364
May 23.............	6 ft.	176	36	60	1,020	104	0	1,396
May 23.............	8 ft.	256	76	48	500	68	0	948
May 23.............	10 ft.	56	56	16	904	24	0	1,056
May 23	15 ft.	60	16	20	376	56	0	528
May 23.............	20 ft.	20	0	0	400	0	0	420
May 23.............	25 ft.	12	20	24	152	8	0	216
May 27.............	Surface.	200	0	60	18,800	40	0	19,100
May 27.............	2 ft.	...	0	0	10,100	80	20	10,200
May 27..............	4 ft.	140	100	60	21,550	290	10	22,150
May 27..............	6 ft.	70	50	90	4,580	90	0	4,880
May 27.....	8 ft.	188	56	40	1,184	160	0	1.628
May 27..............	10 ft.	60	92	8	1,256	64	8	1,488
May 27..............	15 ft.	104	56	16	316	16	4	512
May 27.......	20 ft.	40	32	16	404	...	0	492
May 27..............	25 ft.	0	16	20	96	16	0	148
June 3.............	Surface.	...	...	..	.....	...	0	......
June 3.............	2 ft.	170	0	0	28,050	40	0	28,260
June 3.............	4 ft.	0	0	0	88,600	40	0	88,640
June 3.............	6 ft.	0	0	20	15,850	110	0	15,980
June 3.............	8 ft.	160	0	30	14,250	170	0	14,630
June 3.............	10 ft.	80	120	50	5,140	0	0	5,390
June 3.............	15 ft.	80	20	10	1,830	0	0	1,940
June 3.....	20 ft.	60	80	20	950	10	0	1,120
June 3.............	25 ft.	50	20	20	70	70	0	230

EXPERIMENT No. 4.

Cochituate Water (from depth of 30 ft.) located in lake Cochituate. May 31 to June 7, 1895. Temperature, 64°–70°. Color, 0.29.

Date.	Depth.	Number per cc.					
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Total.
May 31	All depths.	31	62	2	2	7	104
June 7	Surface.	350	0	70	380	0	800
June 7	2½ ft.	120	40	80	11,100	50	11,390
June 7	5 ft.	310	0	40	2,030	160	2,540
June 7	10 ft.	32	0	8	44	28	112
June 7	15 ft.	20	0	8	24	8	60
June 7	20 ft.	48	12	8	12	4	84
June 7	25 ft.	24	0	8	32	12	76
June 7	30 ft.	24	48	8	4	16	100
June 7	40 ft.	56	16	28	4	40	144
June 7	50 ft.	40	48	12	20	28	148
June 7	60 ft.	12	56	12	44	40	164

EXPERIMENT No. 5.

Sudbury water located in the Chestnut Hill Reservoir. June 5 to June 19, 1895. Temperature, 67°–72°. Color, 0.57.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
June 5	All depths.	6	0	17	12	72	13	120
June 12	Surface.	120	0	0	520	690	0	1,330
June 12	5 ft.	0	0	0	9,500	100	0	9,600
June 12	10 ft.	32	0	20	980	140	0	1,172
June 12	15 ft.	16	0	8	776	72	0	872
June 12	20 ft.	16	0	16	112	64	0	208
June 12	25 ft.	0	0	20	68	192	0	280
June 19	Surface.	..	..	..	....	..	..	.....
June 19	5 ft.	40	0	90	28,000	40	0	28,170
June 19	10 ft.	0	0	30	2,870	60	0	2,960
June 19	15 ft.	200	40	80	210	160	0	690
June 19	20 ft.	0	0	12	268	68	0	348
June 19	25 ft.	12	12	60	120	76	0	280

EXPERIMENT No. 5A.

Cochituate Water located in the Chestnut Hill Reservoir. June 5 to June 19, 1895. Temperature, 67°–72°. Color, 0.57.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
June 5	All depths.	0	0	27	4	8	10	49
June 12	Surface.	110	0	0	300	760	0	1,170
June 12	5 ft.	0	0	10	1.840	80	0	1,930
June 12	10 ft.	16	0	4	888	28	0	936
June 12	15 ft.	0	0	40	72	0	0	112
June 12	20 ft.	24	0	20	182	24	0	252
June 12	25 ft.	0	0	36	16	4	0	56
June 19	Surface.	..	..	..	....	..	..	.....
June 19	5 ft.	0	0	20	16,800	0	0	16,820
June 19	10 ft.	0	0	20	10,550	40	0	10,610
June 19	15 ft.	0	0	40	280	20	0	340
June 19	20 ft.	0	0	40	330	0	0	370
June 19	25 ft.	0	0	90	60	0	0	150

EXPERIMENT No. 6.

Cochituate Water (from depth of 60 ft.) located in the Chestnut Hill Reservoir. July 11 to July 26, 1895. Temperature, 69°–77°. Color, 0.58.

Date.	Depth.	Number per cc.					
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Total.
July 11	All depths.	2	30	8	4	0	44
July 26	Surface.	0	0	0	328	0	328
July 26	2½ ft.	0	32	0	8	0	40
July 26	5 ft.	0	0	0	4,400	0	4,400
July 26	7½ ft.	0	0	0	1,472	0	1,472
July 26	10 ft.	0	0	0	140	56	196
July 26	12½ ft.	0	72	0	32	12	116
July 26	15 ft.	0	60	0	48	68	176
July 26	17½ ft.	0	0	0	32	24	56
July 26	20 ft.	0	24	0	8	0	32
July 26	25 ft.	0	0	0	12	4	16

EXPERIMENT No. 7.

Reservoir Water located in Lake Cochituate and Basin 3. August 7 to August 17, 1895. Temperature, 70°–78°. Color: Lake Cochituate, 0.28; Basin 3, 0.68.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Cyclotella.	Total.
August 7..........	All depths.	0	0	25	0	84	3	112

Lake Cochituate.

August 17..........	Surface.	6	0	0	78	102	0	186
August 17..........	$2\frac{1}{2}$ ft.	0	0	0	72	432	20	524
August 17..........	5 ft.	0	0	0	82	212	12	306
August 17..........	$7\frac{1}{2}$ ft.	..	..	..	..	..	..	...
August 17..........	10 ft.	0	0	0	20	184	30	234
August 17..........	15 ft.	0	0	0	2	50	12	64
August 17..........	20 ft.	0	0	4	8	56	24	92
August 17..........	30 ft.	0	0	0	6	46	2	54

Basin 3.

August 17..........	$2\frac{1}{2}$ ft.	0	0	18	28	340	26	412
August 17..........	5 ft.	0	0	0	52	158	46	256
August 17..........	$7\frac{1}{2}$ ft.	0	0	0	12	140	2	154
August 17..........	10 ft.	0	0	0	8	38	0	46

EXPERIMENT No. 8.

Cochituate Water located in the Chestnut Hill Reservoir. November 8 to November 30, 1895. Temperature, 40°–45°. Color, 0.83.

Date.	Depth.	Number of Standard Units per cc.						
		Diatomaceæ.	Chlorophyceæ.	Cyanophyceæ.	Fungi.	Infusoria.	Total Organisms.	Amorphous.
November 8.......	All depths.	463	4	487	1	36	991	280
November 12.......	Above surface.	1,278	30	580	4	27	1,919	376
November 12.......	Surface.	1,564	0	632	16	136	2,348	440
November 12.......	2½ ft.	664	5	532	0	95	1,296	308
November 12.......	5 ft.	676	17	488	8	20	1,209	344
November 12.......	7½ ft.	520	0	564	12	8	1,104	324
November 12.......	10 ft.	475	0	476	0	11	962	448
November 12.......	15 ft.	527	3	384	0	16	930	284
November 12.......	20 ft.	437	0	456	0	34	927	240
November 16.......	Above surface.	1,381	0	355	0	20	1,756	555
November 16.......	Surface.	3,075	0	680	0	117	3,872	685
November 16.......	2½ ft.	1,055	13	265	0	83	1,416	375
November 16.......	5 ft.	665	13	600	15	14	1,307	295
November 16.......	7½ ft.	440	20	460	0	7	927	310
November 16.......	10 ft.	543	15	515	0	67	1,140	375
November 16.......	15 ft.	375	9	465	0	0	849	270
November 16.......	20 ft.	514	0	375	10	0	899	280
November 23.......	Above surface.*	1,051	0	0	0	4	1,055	850
November 23.......	Surface.	3,464	0	460	0	0	3,924	860
November 23.......	2½ ft.	859	0	470	0	7	1,336	680
November 23.......	5 ft.	261	0	240	0	15	516	345
November 23.......	7½ ft.	103	0	215	0	4	322	310
November 23.......	10 ft.	65	0	155	0	0	220	190
November 23.......	15 ft.	....	..	...	..	...	....	....
November 23.......	20 ft.	130	0	40	0	4	174	255
November 30.......	Above surface.	....	..	...	..	...	....	....
November 30.......	Surface.	3,681	0	50	0	25	3,756	1,115
November 30.......	2½ ft.	1,043	18	220	0	5	1,286	965
November 30.......	5 ft.	248	0	110	0	4	362	700
November 30.......	7½ ft.	259	0	95	0	4	358	710
November 30.......	10 ft.	168	0	25	0	0	193	600
November 30.......	15 ft.	....	..	...	..	...	...	....
November 30.......	20 ft.	149	0	10	0	20	179	460

* Sample frozen.

EXPERIMENT No. 9.

Cochituate Water located in Lake Cochituate and the Chestnut Hill Reservoir.
November 22 to 29, 1895. Temperature, 42°-46°.
Color: Lake Cochituate, 0.33; Chestnut Hill Reservoir, 0.90.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
November 22.....	All depths.	824	244	8	24	8	8	1,116

Lake Cochituate.

November 29....	Surface.	2,820	675	20	0	0	20	3,535
November 29.....	2½ ft.	2,540	285	10	0	10	0	2.845
November 29.....	5 ft.	2,180	290	10	0	50	0	2,530
November 29.....	7½ ft.	1,485	495	5	50	5	0	2,040
November 29.....	10 ft.	840	110	0	0	0	5	955
November 29.....	15 ft.	290	205	15	0	0	10	520
November 29.....	30 ft.	520	360	10	40	20	0	950
November 29.....	50 ft.	285	520	10	0	15	5	835

Chestnut Hill Reservoir.

November 29.....	2½ ft.	1,070	125	10	0	10	0	1,215
November 29.....	5 ft.	770	230	5	0	20	0	1,025
November 29.....	7½ ft.	840	310	5	0	0	0	1,155
November 29.....	10 ft.	485	140	10	0	0	0	635
November 29.....	15 ft.	470	145	25	0	0	0	640

EXPERIMENT No. 10.

Lake Cochituate Water located in Lake Cochituate and the Chestnut Hill Reservoir. November 29 to December 9, 1895.
Temperature, 40°–44°. Color: Lake Cochituate, 0.33; Chestnut Hill Reservoir, 0.84.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
November 29	All depths.	625	150	13	17	0	5	810
Lake Cochituate.								
December 9	Surface.	3,010	685	35	60	0	0	3,790
December 9	2½ ft.	1,570	505	25	0	0	0	2,100
December 9	5 ft.	1,240	240	40	20	0	0	1,540
December 9	10 ft.	990	270	0	0	0	0	1,260
December 9	15 ft.	865	260	15	0	20	0	1,160
December 9	20 ft.	680	230	15	0	30	0	955
Chestnut Hill Reservoir.								
December 9	Surface.	895	435	40	60	50	0	1,480
December 9	2½ ft.	1,125	265	20	0	10	0	1,420
December 9	5 ft.	965	260	30	0	0	0	1,255
December 9	10 ft.	510	170	55	10	0	0	745
December 9	15 ft.	110	430	20	60	55	0	675

DISCUSSION.

Mr. Forbes. I was much interested in Mr. Whipple's paper. Two points I would like to touch upon. In the first place, we find that diatoms differ nearly as much among themselves as the larger plants we can see with the naked eye. I think there are now nearly 10,000 diatoms which have been named. Many of them have different habits. Mr. Whipple has spoken, I think, only of the diatoms Asterionella, Tabellaria, and Melosira, Cyclotella, Stephanodiscus, as behaving in a certain way. I have found in our Brookline reservoir the diatom Coconema and Cymbella occurring very freely at a depth of twenty feet. When the reservoir had been full for quite a long time and I had drawn it off, I found these two diatoms growing abundantly on the bottom. They are not free swimming, however. In the second place I would like to say a few words in relation to diatoms being kept near the surface by a movement of the water vertically. As most of you know we have in Brookline a covered reservoir and an open reservoir. The open reservoir is kept nearly full of water to be used in case of an accident to our pumps or a break in the main. Last winter, after the reservoir had been frozen over for several days, and the snow had covered the ice, and there had been no water pumped into the reservoir or drawn from it for several weeks, one quiet morning I cut a hole through the ice and took a sample of water quite near the surface, perhaps half a foot below the ice. I found the diatom Asterionella in large numbers in the water, which would seem to point to the fact that this diatom at least had the independent power of keeping itself near the surface. I have also found Synedra quite near the surface of the water under similar conditions, whereas other diatoms seem to prefer to live near or on the bottom. As, for instance, many species of Navicula, you expect to find crawling along on the bottom of rather shallow ponds. As I said before, the diatoms are extremely numerous, and they all have their own ideas of how they wish to live and intend to live. These are the particular points I wished to bring out.

Mr. Whipple. Mr. Forbes' observation on the growth of Asterionella in the Brookline reservoir is an important one. Such facts should not be lost sight of when considering the relation between light and the growth of micro-organisms. Other cases similar to

that of Brookline reservoir might be mentioned. For example, in Waltham reservoir, which is an open one and which receives its supply from a filter gallery, Asterionella is found all the year round, and is almost equally abundant in winter and summer. In all these reservoirs where winter growths of diatoms occur we find an almost colorless water, and there is good reason to believe that even when the surface is frozen over the light penetrates the water to a considerable depth.

I agree with Mr. Forbes that we cannot insist too strongly that each micro-organism be studied by itself and its own life history determined. No two of them are just alike and no two of them obey just the same laws. In the case of the diatoms some are motile and others are not. The movements of diatoms have excited the interest and attention of microscopists for a good many years, but the cause of their movements has not yet been definitely established. Most observers agree, however, that these movements cease when the diatoms are placed in the dark. It may be possible that the Asterionella referred to by Mr. Forbes are an illustration of the verse of Scripture, "To him that hath shall be given." The Asterionella being present in a colorless water and supplied with a certain amount of light may have had their motility so excited that they remained near the surface, or possibly rose towards the surface where the light was stronger. Whether this was the case or whether there were slight connection currents in the water tending to keep the diatoms settling we do not know. A series of temperature observations taken under the ice at different depths and at different times would have been interesting in this connection.

MAKING CAST IRON PIPE.

BY JESSE GARRETT, PHILADELPHIA.

[*Read and illustrated by stereopticon, June* 10, 1896.]

In the reign of Henry IV. of France, a water engine was constructed for a special supply to the Louvre and the Tuilleries. On its front were illustrated the figures of Christ and the Woman of Samaria, and the name engraved upon it was "The Pump of the Samaritan."

For its universal efficacy in all phases of sanitation, in all ages of the world, the dispensing of water easily relates itself, not only to the *Well* of Samaria (of tender memory), but to the *mission* of the Good Samaritan, bestowing healing and joy by the wayside.

In this spirit men have reasoned together from the dawn of history how best to distribute to their craving fellows God's bountiful gift of water, and, in this spirit, men, and women too, still reason together to magnify the ministering office, to multiply the resources for fulfilling the mission of the Good Samaritan. In this spirit let us reason together to-day.

HISTORY OF PIPES.

The history of the various kinds of pipes for the conveyance and distribution of water, as regards the dominance of each, might be divided into four periods, as follows: The Age of Lead, The Age of Wood, The Age of Stone, The Age of Iron.

The transitions from the one to the other in the first three periods were not however, sharply defined, for each obtruded upon its successor for many centuries, and none obtained the domination that cast iron has now reached, and, to all present appearances, will continue to hold, notwithstanding the fact that steel-riveted conduits for large supplies and long distances appear to be winning the attention of engineers. Many occurrences would seem to imply, however, that we are yet in the very early educational period regarding the latter, while a century of cast iron has demonstrated its staying quality and established its claim to rule. The approaching important questions

of extending the London water system, reaching out to the lakes of Wales, one hundred and fifty miles or more from the city, and of New York and Philadelphia by going to the head waters of the Hudson and the Delaware, may bring steel pipe more closely to the attention of the engineering world.

But again, the double system, separating the water for domestic from that for public use, as now employed in Paris, is probably a coming query to be answered in all our large cities, in which cast iron pipe must necessarily retain its present strong position, and a friendly rivalry between the two constructions may not materially interfere with the success of either.

THE AGE OF LEAD.

Leaden pipes, as a distributing medium, appear to extend back to the dawn of history. In the ancient cities of Asia, Egypt, and Greece, they were used to convey water where the pressure was too great for earthenware. In the reign of King David, in a city of the Province of Zobah, afterwards Aleppo, lead pipes probably predominated, though some of stone or earthenware have been found, as also in the Temple of Solomon, and in public works of his reign.

In his engineering schemes Archimedes used lead pipes largely, and it was through lead that water was ultimately carried to the gardens of Babylon, after earthenware had been abandoned as unequal to the pressure. Greece, in all things tending towards refinement and luxury, led the advance in the most ancient times, and set the subsequent pace for Rome.

In Pope's translation of the Odyssey, we have these lines :—

> "The stream in pipes beneath the palace flows,
> And thence its current in the town bestows:
> To various uses various currents bring;
> The people some supply, and some the king."

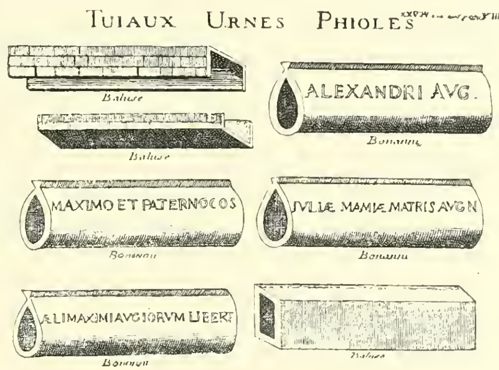
Though in their wondrous works of utility and beauty the Romans as conquerors adopted the prevalent ideas, methods, and materials of the subjugated peoples, their marvellous powers of adaptation and the magnificent results obtained were worthy to rank as original creations.

From the foundation of Rome, contemporary in Biblical history with the reign of Zachariah, for four hundred and forty years the

people were content with the waters of the Tiber and such as their various pools supplied. In their earliest construction of water works they borrowed the idea of lead pipes from the Greeks. These pipes were made of leaden sheets soldered together, and were in various lengths, mostly, however, of ten feet, and from one to twelve inches in diameter. Various eccentricities of form are described; some were cylindrical, but mostly oval, with the seam at the apex.

It was, even in those early days, a subject of discussion, and by some seriously averred that lead pipes poisoned the water, and this question, so early raised, remains a question of debate with you to this day.

The distribution lines, carrying water to and through the bathing places and the houses, were the property of the state, and the use was granted to families and individuals, whose names were required to be engraved on the pipe, and these, in the excavations now going forward, locate the residence of this or that personage, and many men of note are so traced to-day to their ancient homes. At the period here described, within the walls of Rome were eighteen hundred palaces and fifty thousand houses of the people who numbered one million.



The mazes of these pipes through the streets of the cities of Babylon, Rome, Pompeii, and many others, bewilder the archæologist, and the student who attempts to follow his interesting recitals. In all these cities the trail of the water pipes leads to the verification of old story, and the unfolding of new, as thousands of tons of pipes are unearthed in the explorations.

The Roman Baths are most notable, especially those of Caracalla, 217 A. D., and Diocletian, 295 A. D., with their intricate network of pipes supplying cold water, hot water, and tepid water through separate systems, mostly of lead, some of wood, and a few of earthenware. It will be interesting to look at the figures from the standpoint

of the Water Registrar. The capacity of the Diocletian system, for instance, was equal to the accommodation of 18,000 bathers at once, and the daily period of the baths was about three hours; allowing a half hour for each bather, 108,000 persons were refreshed daily, with an expenditure of water in each of the three compartments, the tepid, the hot, the cold, of over 1,140,000 cubic feet, or, in all, about 25,000,000 gallons of water for one system of baths daily. But this, even, seems insignificant, when drawn from a daily supply of 385,000,000 gallons.

The cold water came directly to the "Frigidarium," from a reservoir supplied by one or more of the great aqueducts. The tepid water, similarly supplied to a great reservoir, was warmed by the sun, and conveyed thence in lead pipes to the "Tepidarium"; the hot water, drawn from other reservoirs, was heated in copper vessels, and passed on through them to the "Calidarium."

Besides these, were the pipe systems for their many beautiful fountains, surrounding which were seats inviting all classes to tarry and enjoy their refreshment.

Again were other systems of piping for private houses. Rudolfo Lanciani, a most ardent archæologist and poetic writer now exploring and writing, goes farther than indicated above and says: "At the crossing of roads there were fountains for the accommodation of travellers and their horses; in fact, the gentleness and tenderness of those happy generations went so far as to provide weary pilgrims with seats shaded by trees, where they could rest during the hot hours of the day."

For purposes of domestic supply, and in the general spirit of sanitation, Agrippa alone constructed seventy pools, one hundred and five fountains, and one hundred and thirty reservoirs. Truly, the ancients believed, as one of their writers said, in the most generous distribution of the "bounty of the gods."

Though in our many public parks and still-multiplying enterprises for the public good, we are not without commendable effort towards such benefactions as are described, we by no means reach the wondrous achievements of the ancients, and we may yet learn something from the heathen Samaritan.

From the decline of the old civilizations there is not much progress to note in water supply in any countries for many centuries. Wherever small, new systems were established, or old ones extended,

lead appears to have been still the prevailing material for distribution.

Not until the year 1236, is there much new record accessible. In that year, London began to lay a 6-inch main from springs at Tyburn, where the water was collected in a cistern of stone, lined with lead, situated some miles distant. This is supposed to have been the first attempt of that great city towards a public water supply, and even this small system took fifty years to complete; and it does not even appear that water was distributed to private houses until the year 1582. The pipes that were laid down in this primitive effort were dug up in 1745, and were of the old construction of soldered sheet lead. As time went on, different methods of manufacture came into vogue, and about the beginning of the sixteenth century they began to cast lead pipe in short lengths, vertically, and, later on, in longer lengths; the first pipe being cast and drawn upwards through its flask till the lower end was near the inlet gate, the metal of the second pouring fusing with the first, and so on, to the desired length.

A quaint, old chronicle of 1749 describes the stealing of water from the mains in public streets as follows: "This yere a chandler in Flete Street had by craft perced a pipe of the condite withynne the ground and so conveyed the water into his selar: wherefore he was judged to ride through the citie with a condite upon his hedde."

I find also a curious record about this time, which, although not altogether relevant to pipes, will be interesting to those of you who have water rents to collect. In 1439 the Abbot of Westminster granted the Mayor and citizens of London "one head of water," twenty-six perches in length, and one in breadth, with all its springs, in consideration of which rent the city is forever to pay at the Feast of St. Peter "two peppercorns." You may like to muse upon this whilst holding your quarterly celebrations, receiving the offerings from a glad public, and maintaining a sweet demeanor, at *your* "Feasts of St. Peter."

Henry VI. afterwards confirmed this grant, and a law was passed to put to death those who were found destroying pipes, which may be considered good positive evidence of the continued use of lead or wood, and circumstantial proof that cast iron had not come.

A French writer mentions lead pipe for a height of 400 feet, 20 inches in diameter, 5½ inches thick; also copper pipes for same

diameter and height, $1\frac{1}{12}$ inches thick. This writer says: "Cast iron is not used because it will not resist the loads of vehicles by which they would be likely to be broken, and it is impossible to get out any of the fragments."

The most ancient aqueduct for supplying Paris was that of Prés-Saint Gervais, and belonged to the Abbe St. Laurent. The hills about supplied it with water, through lead pipes, from a reservoir. About 1600, Henry IV., whose name occurs most frequently of any of the monarchs in the encouragement and promotion of water supplies, erected a pump, previously spoken of as that of "La Samaritaine."

A work written about 1700 cites, as one of the curiosities of Augsburg, Germany, towers to which water is raised through large leaden pipes, from which distribution is made to smaller pipes to one thousand houses and to public fountains, at a cost of *eight crowns yearly.*

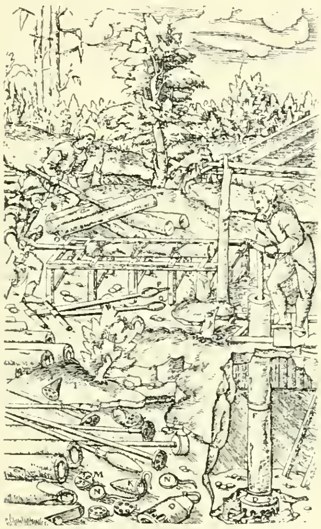
Another old account describes fresh water as being obtained from the bottom of the sea by sinking large bells or cylinders of lead, to the upper portions of which were attached pipes of leather, from which, probably, our leather fire hose is descended.

To conclude the episode of lead, which prevailed during the period spoken of in Paris, Glasgow, and other large cities, almost the entire system of London being of this material, the pipes in the Great Fire, in 1666, were melted, and, while the immediate substitute was of wood, an impulse was given towards a better pipe for water, and, under continued experiment and failure, a slow development progressed towards cast iron, which I will speak of and illustrate later on.

THE AGE OF WOOD.

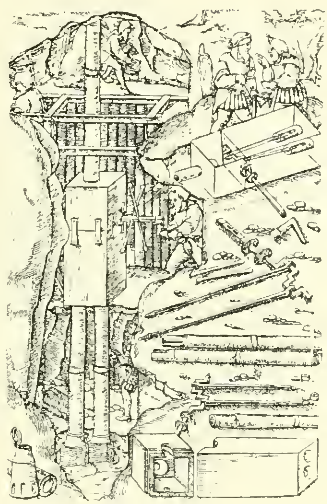
The wood dynasty appears to have contested the field with lead almost from the beginning with a potency and persistency that, for many centuries, gave it a most important position in water supply systems, and enabled it ultimately to occupy the foremost rank for two or three hundred years until, itself superseded by cast iron, but with fitful manifestations of life, to this day. Ewbank quotes from "Pliny's Work on Gardens," describing the use of different kinds of wood. He says: "Pine pitch trees and allars are very good to make pumps and conduit pipes to convey water, for which purposes

the trunks are bored hollow," and he supposes these to be of ancient origin. I do not know, but it may be this allar tree was a larger growth than we know, of the pithy alder or elder, which other accounts speak of as being used for such purpose. For instance, in



[*From Agricola's "De re Metallica,"* 1556.]

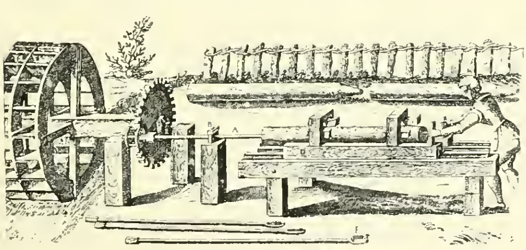
BORING LOGS FOR WATER PIPE.



[*Agricola*, 1556.]

LIFT PUMP OF LOGS.

the Encyclopedia Britannica, dated 1797, I find the following: "Pipes for water, water engines, etc., are usually of lead, earth, or wood, the latter of oak or elder." *



[*From "Raisons des Forces Mouvantes,"* 1615.]

BORING LOGS — IMPROVED APPARATUS.

Nothing of more than ordinary importance occurred to disturb the relative position of lead and wood in the ancient practice, or in the latter slow development of water works in Europe, till after the fire

* Anglo Saxon, "ala." Elder, in Anglo Saxon ala tar, hollow tree.

of London, which has before been noted, when the use of wood, that had already been employed to some extent, began to supplant lead, until the latter for street mains was entirely displaced. For a time after the fire, water was distributed by water carriers with buckets.

The "New River Company," the oldest of the family of water works now supplying the city of London, was chartered about 1600 by James I. Its distribution aggregated a length of four hundred miles of wooden pipe, requiring frequent repairs, insomuch that the entire system was renewed about every twenty years. They were of the usual style of pump connections, were coated in a bath of lime water, and, with whiting and tallow, the joints were driven home. But the wastage was enormous, said to be about twenty-five per cent. These logs were in their turn replaced by cast iron as early as 1820, at a cost of £1,500,000. The many other companies then supplying London soon followed, and the most extensive equipment of wood pipe distribution ever in existence, passed away.

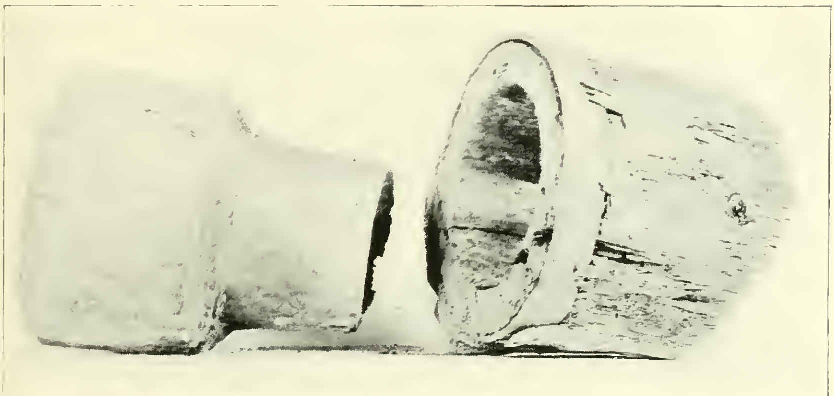
In addition to the wood pipes, there were also in use those of stone ware, of coarse glass, and in Peru and Mexico even silver water pipes were found at the time of the Conquest.

NOTE.—In the *Scientific American*, Sept. 22, 1883, can be found this description of paper pipes for water, which were made by "passing a continuous slip of hemp paper, the width of which equals the length of the tube, through a bath of melted asphalt, and rolling it tightly and smoothly on a core of the required diameter till the number of layers is sufficient to make the desired thickness, when the tube is strongly compressed—the outside sprinkled with fine sand, and the whole cooled in water. When cold, the core is drawn and the inside washed with a waterproof composition. These pipes were said to have great strength, when about one-half inch thick, withstanding a pressure of two hundred pounds, not broken by settlement, poor conductors of *heat*, and do not freeze."

The first water works at Philadelphia used wood for distribution until after the beginning of the present century, when their replacement by cast iron was begun, and of which I will speak more particularly later on.

The earliest water works of record, however, in this country were those of the city of Boston, built in 1652, and more sluggish and dilatory to advance after that, was our sister city, than can be conceived when we consider the wonderful pioneer service she has done now for many years. They were built, the chronicle says, for fire service and domestic supply. The name of the system was the

"Ancient Conduit," and consisted of a reservoir, about the region of Dock Square, spouting water round about, when needed. through the pipes of lead or wood. No advance beyond this is recorded till more than a century later (1796) when water was brought from Jamaica Pond through four pipes of pitch pine log, two of 4-inch bore, and two of 3-inch bore; the combined length of the two lines being about



WOODEN PIPE LAID FROM JAMAICA POND.

fifteen miles. This enterprise was conducted by what was called the "Aqueduct Corporation." In 1825, city ownership was advocated, under the then Mayor Quincy. Not till 1840 does it appear that wood was superseded by iron, at which time "a 10-inch main was laid to Bowdoin Square," and not till 1846 were the new city works begun. On July 4 of that year, Cochituate water was first introduced in barrels at Boston Common. To-day Boston may be said to lead the world in water works enterprises, and has under contract and in process of construction the most gigantic system of modern times.

The works of Detroit, Mich., were commenced in 1825, and first delivered water in 1827. The pumps at that time were driven by horse power, and the water pumped into an elevated "cupola," and from thence through pipes of tamarack logs, 4½ inches in diameter, to a reservoir 16 feet square and 6 feet deep, constructed of white oak plank. In 1830 the system was extended, and a ten-horse power steam engine was first used, the second one erected in Michigan.

The water by this engine was driven through a three-inch pipe to the reservoir, the first cast iron pipe used in Detroit.

The principal source from which wooden pipes are received at this day is from Michigan, where if anywhere it holds the "age," and there are probably more wooden pipes laid there for water than in all the rest of the country combined.

THE AGE OF STONE.

I pass by the splendor of the great stone conduits of Rome (nine or more in number and aggregating three hundred and fifty miles in length) as being, perhaps, too highly born for our subject. I cannot refrain, however, from quoting a passage from Lanciani, who "rejoices that cast-iron pipes were not known when the aqueducts were reared, because of the beauty the Roman Campagna now affords." In considering stone as a water conveyance, it will be more in its unique variety than in its prevalent character.

Among the ancients I find quoted from Herodotus an interesting description of a conduit to convey water, constructed by Emperlinus for supplying the city of Samos. It was one mile in length, of stone, bored through the centre, 13 inches in diameter, the blocks of three feet, cubical measure. On one end of each block was an annular projection to fit into a recess three inches deep in the abutting stone, a "spigot and faucet." This was laid at places on masonry of 200 feet span and 250 feet height. I find no account of the method of boring these blocks, but following up the thread, one of James Watt's principal assistants, about the beginning of this century, patented an apparatus for boring stone pipes, and these were used in the first work constructed for supplying Manchester, England, about 1810 to 1814.

These were bored from a soft limestone, but were found unequal to the pressure, and, in the fulness of time, were exchanged for cast iron, except for high points.

They were about two feet long, with spigot and faucet joints, sealed by Roman cement, from three to eighteen inches in diameter, and it is interesting to note the prices: 3-inch bore about 27 cents per foot; 6-inch bore about 90 cents per foot; 12-inch bore about $2.50 per foot; 18-inch bore about $3.65 per foot.

NOTE.—In the previous mention of stone pipes, I have passed by the earthenware, which are sometimes so classed, and in Rome were frequently used, connected with screw joints. Very ancient conduits have been exca-

vated in the Island of Cyprus, ten feet below the surface, and these were made of red clay, about one foot in diameter, with spigot and faucet joints, filled with cement and coated with bitumen.

Lanciana describes mains of stones, the mouths of which were of marble, grotesquely carved. These, he assumes, were of the sewer system of Rome, as, from their position, it would appear that they were placed to empty their contents into the Tiber.

THE AGE OF CAST IRON.

Regarding the discovery of iron, our own Professor Drown said, in an address some years ago, that all stories of original discovery developed from fancy, with a basis of truth; and this was probably the foundation of the legend that iron was first found after the large forest fires on Mount Ida thousands of years ago, which fused the ore lying on, or near, the surface of the earth.

At a general meeting of the German Iron Founders Association, held in Wiesbaden, Dr. Beck, of Biebrich, read a paper on the history of iron casting, in which he stated that "the first find of metal was a piece of iron which was discovered in the foundations of an Egyptian pyramid three thousand years before the Christian era."

During all the early ages of iron, it was only used in forged product for weapons of war or architectural purposes. The pillars at the gate at the Temple of Delhi weighed thirty-eight thousand pounds, were twenty-four feet high, sixteen inches in diameter at the bottom and twelve inches at the top, on which it is said that no method of cutting now employed can make a mark.

Cast iron was known to Holland in the 13th century, and stoves were cast at Elass in 1400. But tradition has it, which an ancient Roman writer records, that the temple of the "Great Mother" at Sparta is said to have been built by Theodorus, who first discovered the art of casting and making statues in iron. All this is necessarily vague, a condition which suggests a quotation from Dr. Greene, of the Boston Historical Society, in reference to the present disturbance of King's Chapel burying ground for the subway human conduit. "It is so full of bones and remains that I do not believe you could dig down to the depth of much more than an inch without turning up the dust of ancient worthies." The application is this; that in the dust of these "ancient worthies," it is impossible to verify the individual instance.

As with the metal itself, so its discovery in the form of cast iron was an accident which occurred at one of the early iron works in the Rhine Provinces, where a part of the "running" one day was found to be of different texture, and it was a problem for some time what to do with the strange stuff.

The first blast furnaces appeared in the Thuringian Mountains, which were almost identical in principle with the present furnaces, with the exception that hand or tread-mill bellows were used for the blast, from which the present mechanical blowers are an evolution. In 1377, the first cast iron gun was cast in Erfurt, and the famous Krupp was casting guns in 1818, so that it appears iron was mostly used for destructive, and not Samaritan, purposes through many centuries of its history.

In 1685, the first cast-iron pipes were used for the water service of Versailles, followed by screwed and flanged pipes. In 1708 the Quaker, Darby, patented the system of box casting, and in the following year started the famous Coalbrookdale Foundry, which in 1780 turned out the first cast-iron bridge. The first casting in the United States is said to have been made at Lynn, Mass., — a cast-iron pot, — which was exhibited at the World's Fair at Chicago.

In the region of Alba Longa, buried by the volcanic eruption which drove the Albans to the present site of Rome, no trace of iron is found, and its absence is still notable in the archaic tombs of Rome. The metal for their implements, of whatever kind, was of bronze, and the early Roman religious sentiment shows such an abhorrence of iron as to make it a profane innovation to use it in almost any form, especially in and around their sacred temples. This superstition continued after the Christian Era, even down to the fall of the Empire.

In their religious rites, if iron had in any way approached a temple or shrine, sacrifices were instituted to expiate the profanation; so that we can hardly wonder that their attention was not turned to it as a substitute for *lead pipe*. When iron tools came to be used for engraving, and were so employed on certain altar inscriptions, penitential sacrifices were afterwards offered by slaying a cow or a sheep on the altar.

Bronze plows were used long after the introduction of iron plows. The High Priests of Rome would not shave, or have the hair cut, with iron instruments.

The first mention of iron pipes, I find, was in an elaborate system built at Marli, near Paris, and set to work in 1682, costing one and a half millions of dollars. The account says: "They drew the water by short suction pipes from the river Seine, and forced it through iron pipes up the hill. They climbed to a height of five hundred and thirty-three feet by a series of reservoirs and pumps, but this system came to be known as a 'monument of ignorance,'" probably after cast iron established confidence as a pressure pipe.

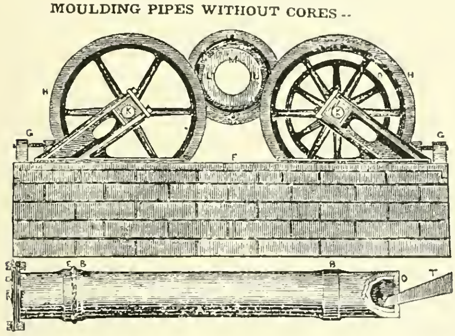
Agricola makes no mention of cast-iron pipes, although he shows three-legged pots of cast iron. Ranselli, about the same period, describes a hand-mill of a portable character, whose casing, he says, is made of iron, and its form and ornamentation is such that there is little doubt it was made of cast iron.

Peter Maurice, a German engineer, in 1582 erected, under the arches of London Bridge, sixteen pumps, seven inches in diameter, and thirty inches stroke, driven by a water wheel, and these were of cast iron, flanged at their lower end, bolted to a valve chest.

In 1835, it was estimated that over one thousand miles of iron pipe were in use in the various systems of London water works; the first iron pipes having been laid in 1746.

Later on we find that cast-iron pipes, nine feet in length, and fifteen inches in diameter, with ball and socket flexible joints, were laid by James Watt, across the Clyde, for the conveyance of water to Glasgow, and another of the same size in 1818, and a little later on, another of similar construction, of thirty-six inches diameter.

MOULDING PIPES WITHOUT CORES.



Among the curiosities of pipe-casting, we find the following English patents: one granted to Anthony George Eckhart, in 1809, for casting metals in revolving moulds, where the metal is poured into the mould, which is made to revolve very rapidly, and the centrifugal force causes it to fill up all parts of the mould; later on, another English patent granted to Andrew Shanks, in 1849. The process is very simple in idea; the small and of the

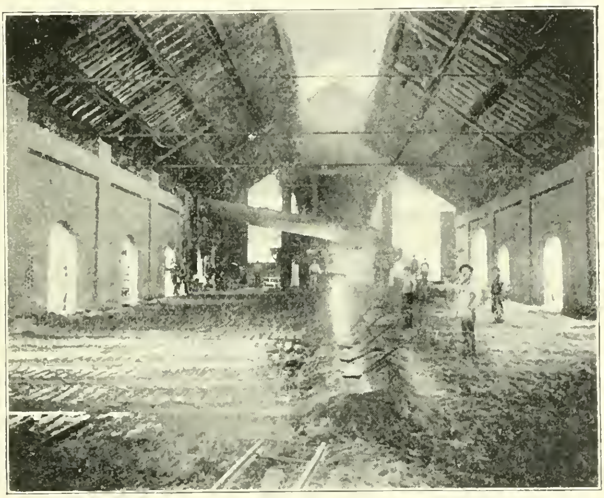
mould is nearly closed with a plate covered with loam, and the large end is also nearly closed by a similar plate, an opening in its centre being left for pouring in the metal. The mould is supported horizontally on friction wheels by which it is caused to revolve, and the fluid metal is distributed (by the centrifugal force, due to rapid rotation) over the interior surface of the mould; and as soon as the metal is cold enough to retain its form, the mould is opened and the pipe removed; if properly made one mould will serve for casting several pipes.

In an old Encyclopædia, I find that this method was used in Baltimore, but I have been unable to locate it in any closer way than by the mere description.

Cotemporary with the history of cast iron pipes in America is Peter Adams, a moulder and core-maker, born in Millville, New Jersey, in the year 1833. His grandfather, James Adams, was a soldier in the Revolutionary War. His father, Mark Adams, was born 1789, and was a moulder and core-maker at Weymouth, New Jersey, where he was engaged on the first cast-iron pipes made for the city of Philadelphia, from designs, and under the instruction and inspection of Frederic Graff, 1st, who was the then engineer of the Philadelphia Water Works, and father of the later Graff, who succeeded him in office. The first pipes made for Philadelphia were for the pumping main, of 16-inch diameter, delivering into the reservoir, the distribution still continuing throughout the city through wooden pipes. These pipes were cast direct from the melting of native bog ore, and the process was about as follows: in the beds where pigs were usually run, were moulds for pipe, which tapped the flow from the furnace, until one pipe was complete, then on to another mould, and so continuing for as many pipes as were planned for that pouring, using the surplus from the pipes for pigs as usual. The proprietor of these furnaces at Weymouth was a Mr. Richards, a native of the city of Philadelphia, and its Mayor at that time. After this, Mr. Adams thinks that the first pipe made at Millville, N. J., was about the year 1830, the inspector for which, under Mr. Graff, he remembers as one Louis Ort, who "was a good fellow enough, but inclined to be very particular unless he got one or two glasses of whiskey before beginning his daily inspection, in which case it was very seldom that he would reject a good pipe."

The first pipes made at Millville, as at Weymouth, were from the product of the bog ore furnaces, and at that time, of course, cast upon their sides, a series of gates, six or eight in number, used for running the iron from the furnace into the pipe moulds, which, at the proper time, were cut off, and the flow of iron continued to another series, or to the pigs, as the case might be.

As time went on, and the demand for cast-iron pipes increased, and sentiment ripened against using the melt direct from the ore, the proprietor of the Millville works, Mr. David Wood, designed and constructed special foundries for their manufacture. The practice of



PIG-IRON FURNACE, SHOWING THE RUNNING OF PIGS.

casting upon the side continued, however, until a much later date, and the first experiment of casting on end was made at Conshohocken, under the then proprietors, Bell & Colwell, about the year 1851. This was a 30-inch pipe, and the largest then ever cast in this country. Probably Mr. Adams is mistaken as to the date, as this is doubtless the pipe made for the city of Boston, spoken of in another place, the contract for which was placed at the Conshohocken works. The first fixtures for the vertical pipe were designed and made by one Alexander Russell. A pipe of this size was at that time of so great a novelty as to excite the curiosity of practical men

Fig: 1.

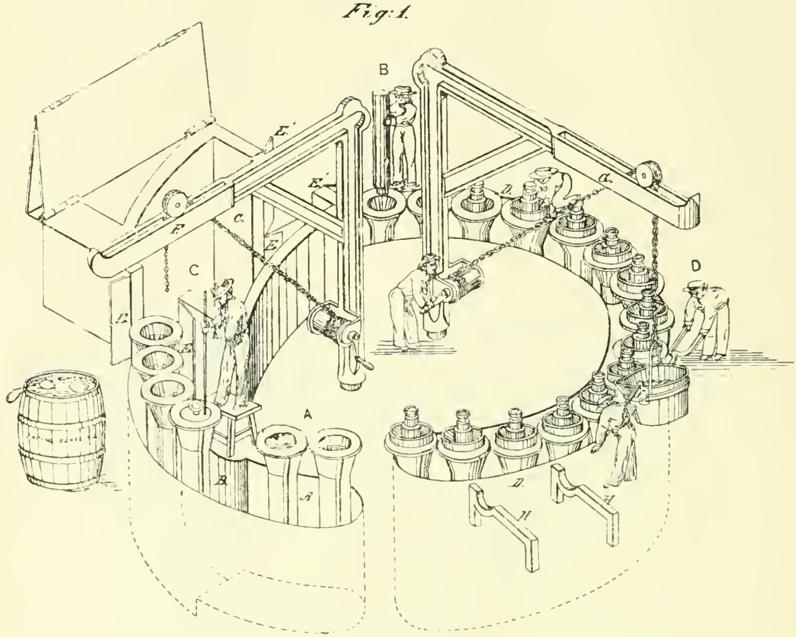


Fig. 2.

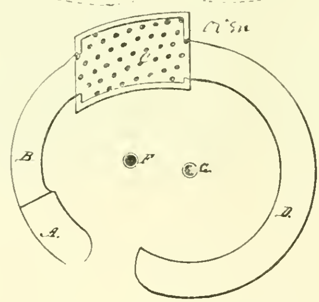


Fig. 1 shows an early English method of pipe casting "heads up." A prevalent practice now is to cast "heads down."

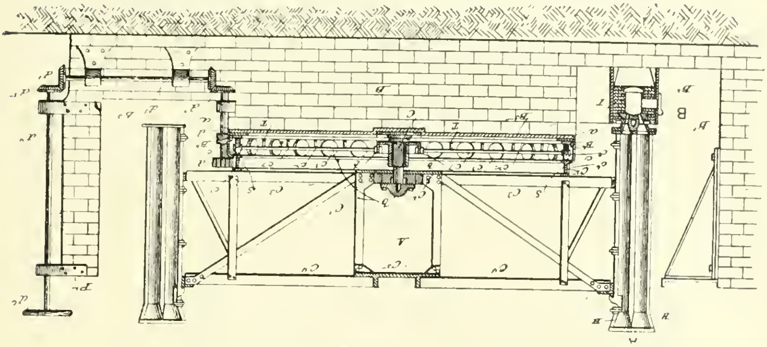
A is the flask.

B the core.

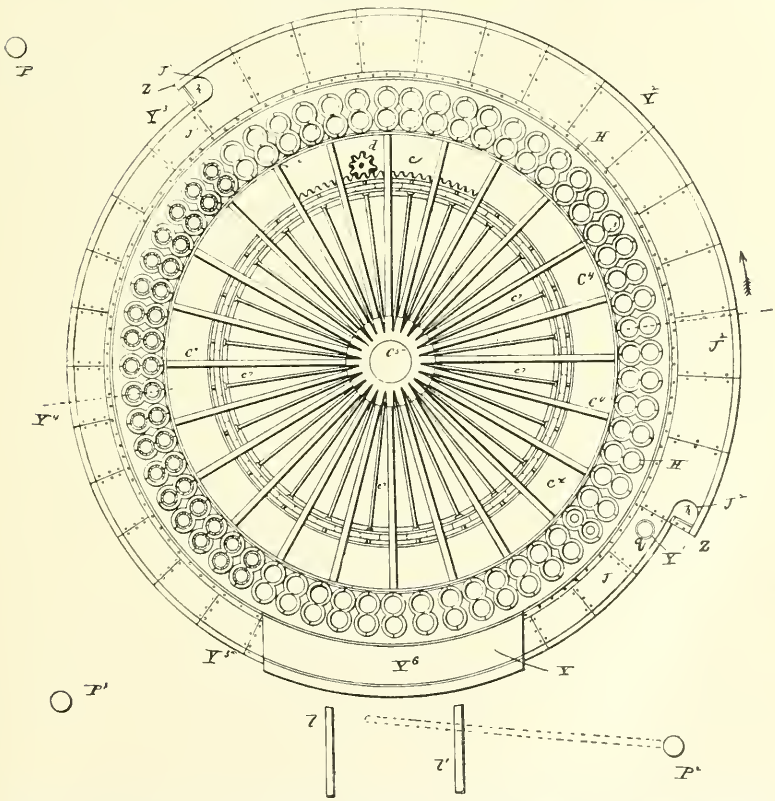
C ramming up the mould.

D pouring the iron.

Fig. 2 shows the plan of the pit with the oven, over which the moulds are placed in succession by the radial crane for drying, the heat ascending through the pipe. The present practice is to use closed ovens, uniformly heated, confining the moulds for hours.



After an English patent. Section of turn-table. Moulding pit.
A moulds. B oven.



Plan of a turn-table pipe-moulding machine, in limited use, showing a full pit of moulds. The pit revolves, carrying the moulds over a drying oven. No crane required.

everywhere, and workmen from the Millville foundry were attracted to the Conshohocken works for the purpose of seeing so rare a production.

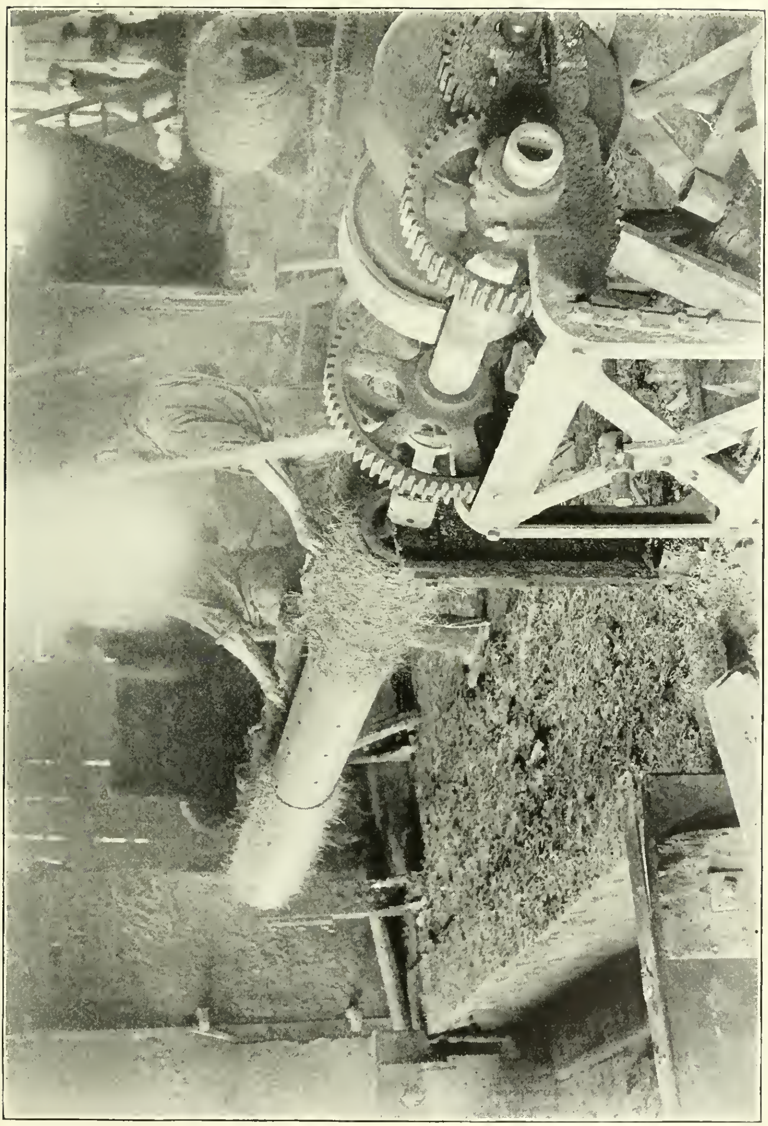
The original proprietor of the Millville iron works, as before stated, was David Wood, a brother of R. D. Wood, who succeeded him, and who afterwards added to his pipe works, from time to time, until their production became the largest in the country, and who was also thoroughly identified with iron and other industries, being one of the very earliest projectors and proprietors of the Johnstown iron works in Pennsylvania.

MANUFACTURE OF CAST IRON PIPE.

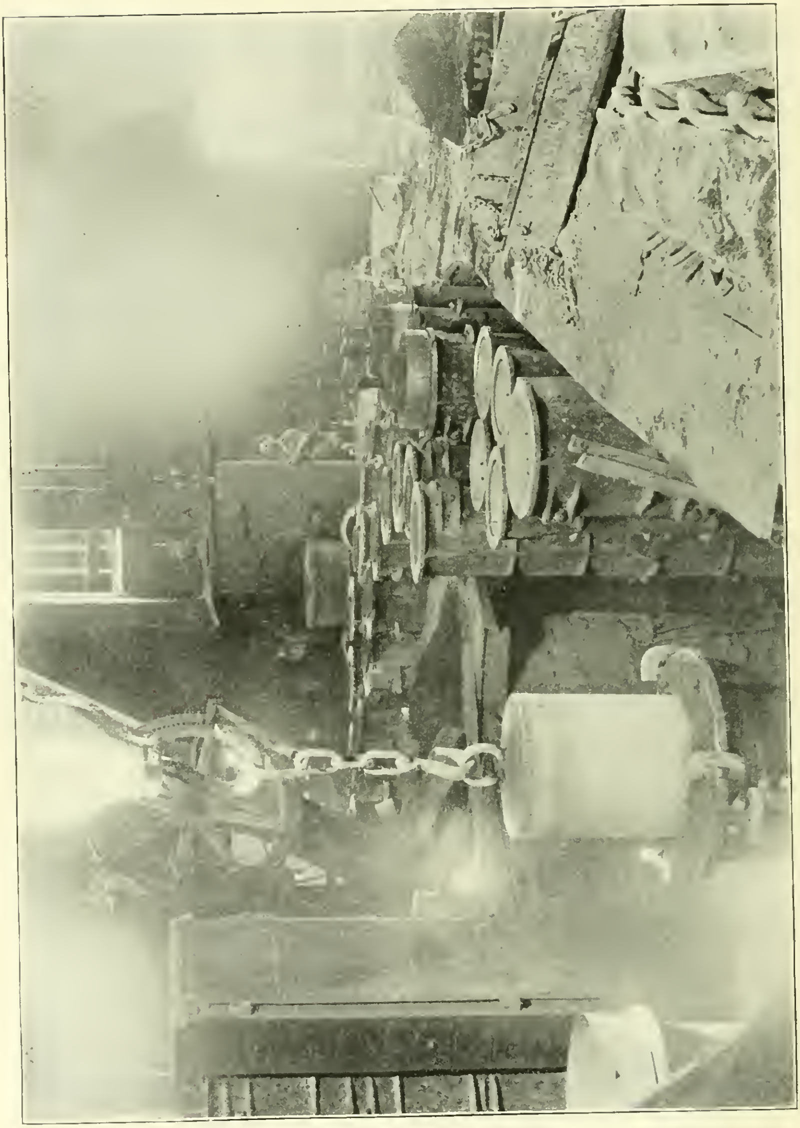
From the ore beds to the blast furnace, from the blast furnace to the cupola, is the course of the basic material for cast-iron pipes. As it comes from the blast furnace it is what is known as "pig iron," and each pig is cast to weigh about one hundred pounds. These before melting are broken in two pieces, in which size they go to the cupola. Good pipes cannot be made of the iron from one blast furnace. It is prevalent practice to use about four varieties of pig iron from various localities and grades of ore by which better results of pipe are obtained. These irons are all re-melted in what is known as the "Colliau" cupola, and, for the last ten years, principally with coke. Before that time were used the best grades of Lehigh, broken anthracite coal. A small portion of coal is mixed with the coke to give it body, and it is also an improvement in other respects. The fuel can be mixed in almost any proportion, from all coke to all coal, with a gradually decreasing speed of melting, although it is found that one quarter or less of coal does not materially reduce the melting per hour. The processes of melting, either by coal or coke, are somewhat similar, though in the use of coke the cupola tuyeres are a little higher from the bottom than for coal, the coke being lighter, taking a larger amount in bulk for what is termed the bed. The depth of bed of fuel depends altogether on the size and proportion of the cupola; the main point being to have the coke from four inches to six inches above the tuyeres, so that the first charge of iron will be above rather than below the tuyeres; if below, it is likely to be the cause of dead iron for the first few charges.

The usual practice for charging, depending as aforesaid upon the size and proportion, is as follows: First, the bed of coal or coke is

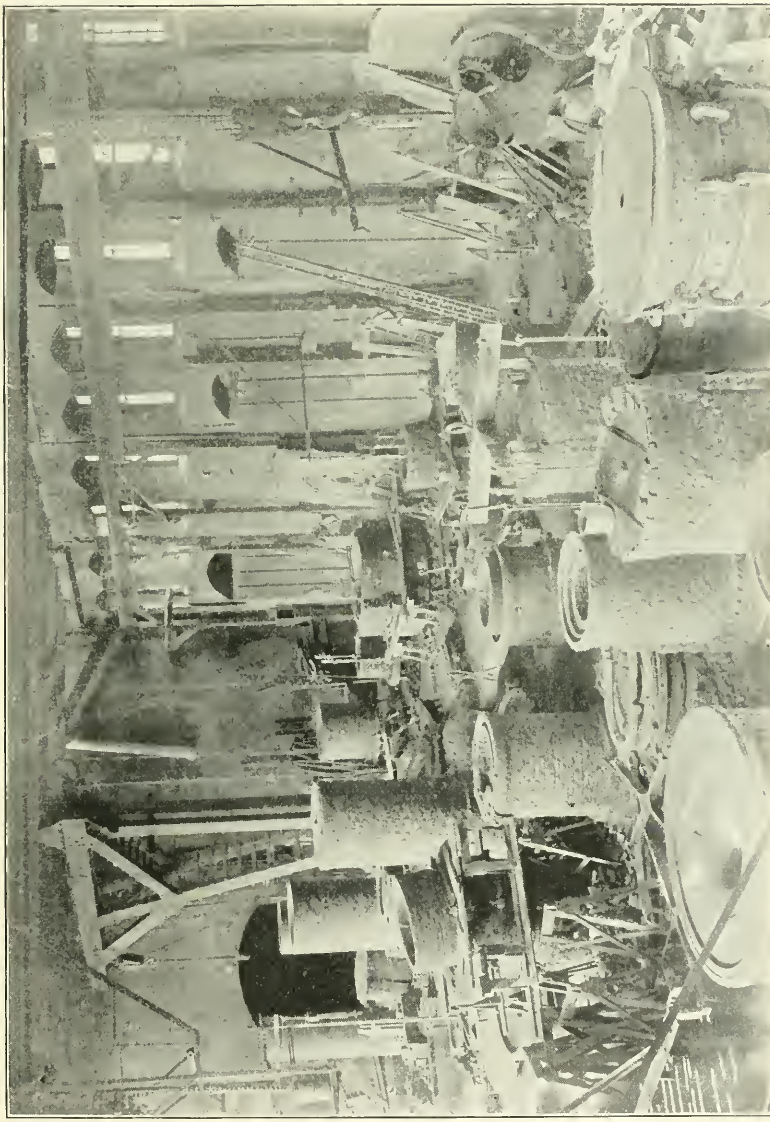
SPINNING HAY ROPE FOR SPINDLES.



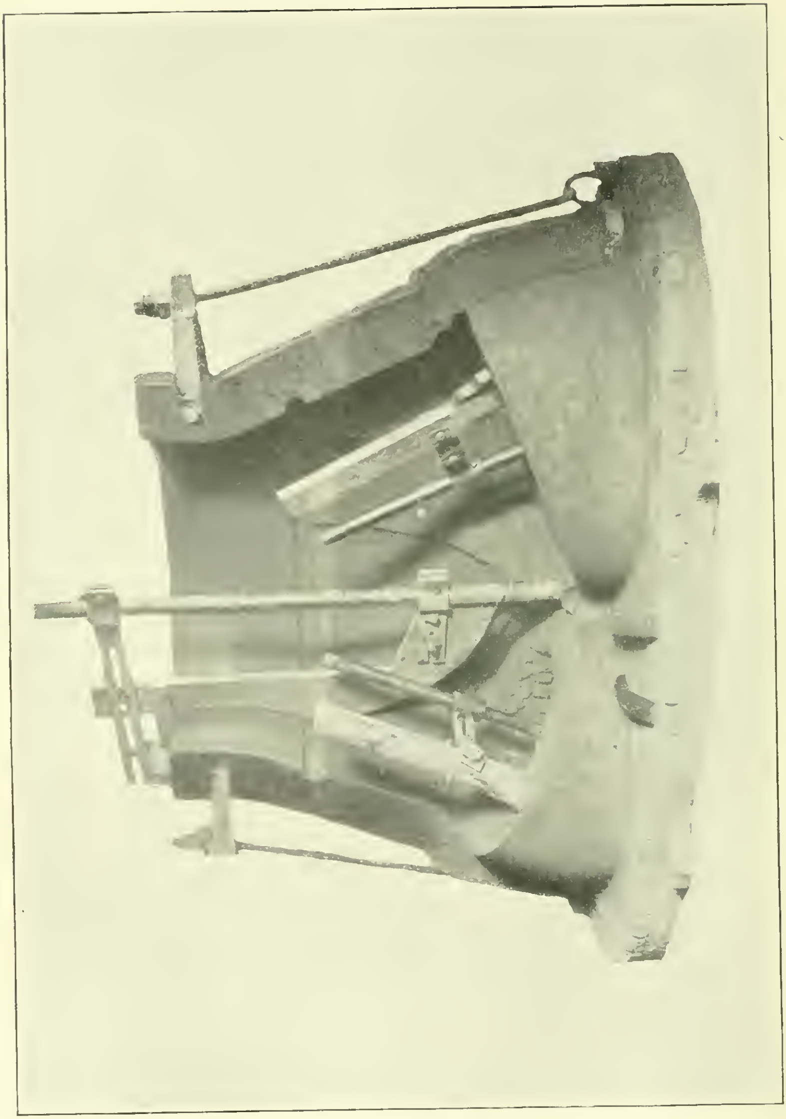
WINDING THE ROPE ON SPINDLE TO BE COVERED WITH LOAM.



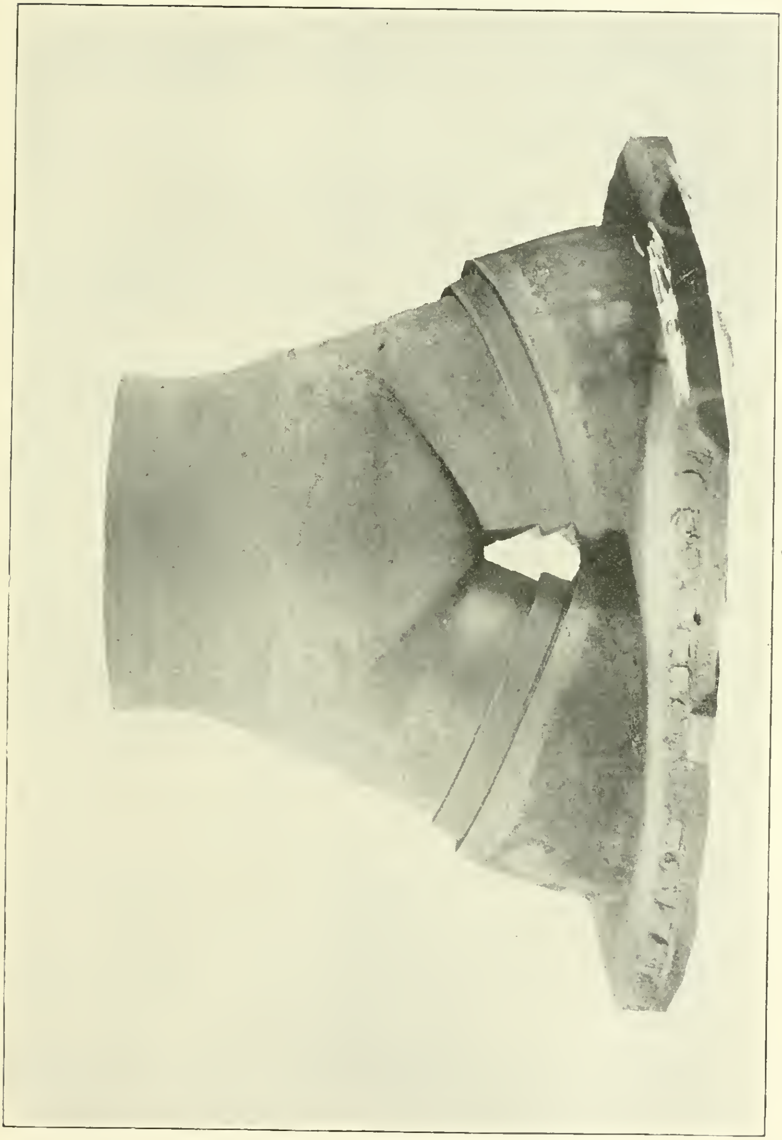
GENERAL VIEW OF PIPE PIT.



LOAM FOUNDRY.



MAKING MOULD FOR BREECHES PIPE.



CORE FOR BREECHES PIPE.

The metal socket ring, D, is also wound with straw roping, covered with sand, and accurately turned. The bead-ring, F, is formed in a turned-iron mould and dried.

When these several parts are dried and combined for casting the pipe, as they are shown in the sketches, the core is accurately centred by the bevel at the bottom and bead-ring at the top, and the space between mould and core will then conform accurately to the desired shape and dimensions of the pipe. The tempering of the sand and drying of the mould, so as to withstand the trying action of the molten metal, are matters that require the utmost care to insure perfect castings. The flasks are finally placed on end in the pit, preparatory to pouring, so as to secure a solid casting, cylindrical in bore, and of uniform thickness upon all sides.

The molten metal is then drawn from the cupola into the ladle and transferred within reach of the pit crane, by means of which it is lifted and poured. After several pipes have thus been cast, the emptied ladle is returned to its truck, and the crane used to quickly lift out the spindles, the hay-rope covering having meanwhile been burned away, admitting of their easy withdrawal; and the pipes are thus allowed to contract freely in cooling. As soon as properly cooled, the flasks and pipe are together lifted from the pit, when the clamps which have served to hold the sections of the flasks together are removed, and the pipes permitted to pass on to the cleaning skids. Single flasks are used for pipe of larger diameters, while in modern practice double and sometimes triple flasks are used for pipe of the smaller diameters.

COATING FOR CAST IRON PIPES.

Humber says: "To avoid oxidation, as far as possible, the metal should be selected, uniformly homogeneous, close and hard in texture; impure, soft foundry iron rapidly corrodes, the close gray and white iron being less destructible than any other." It is quite probable that the modern foundry practice will widely disagree with the opinion above expressed, but it was this condition of foundry knowledge that excited the inquiry of how to protect pipes from oxidation.

In 1866, experiments were made by the French Navy with a varnish of a mixture of sulphur, resin, tar, gutta percha, ceruse, and

turpentine. Pipes so treated were immersed in sea water for a year, and reported quite free from rust.

During these experiments, iron was galvanized by dipping it in boiling zinc, but the preparation was found to blister and peel off, and it was also subject to galvanic action. This was probably similar to the later preparation applied to what was called the "calomeine" process.

Latham, an English engineer, cites an instance at Croydon, in which the subject was a 12-inch pipe, 5/8 inches thick, tested under a pressure equivalent to a 500-feet head. In service it burst under a 150-feet head, in several parts, after a heavy rain followed by snow. Spon calls the condition that may so result, "hide-bound," wherein the texture of the pipe may be affected by sudden extreme change, or even a slight variation of temperature, cold weather being specially favorable to such.

Edison has said that the very few successes he has attained are the results of multitudes of failures, and, in this way, came about the prescription of Dr. Angus Smith, which seemed to reach the proper treatment of the disease. The ingredients of his preparation were simply gas tar, Burgundy pitch, oil, and resin. The pipes, under his experiments, were first dipped while hot, but afterwards it was thought to produce better results to dip them cold, as the composition, in contact with highly heated iron, was injured and did not adhere as well. Five or six per cent linseed oil was a part of Dr. Smith's prescription. This was forty years ago, during which lapse of time modifications have been found to be necessary, desirable, and efficient, as well in the coating as in the iron mixtures and general processes of manufacture. An interesting, special coating for pipes, carrying water from coal seams, is as follows: the pipe was exposed three hours in a bath of hydrochloric acid, then dipped in water, afterwards washed with a mixture, thirty-four parts silica, fifteen borax, two of soda, then exposed in a retort to a dull, red heat, then another coat on the inner surface, and exposed to a white heat for twenty minutes.

The coating which mostly prevailed for the inside of stone, terra cotta, or masonry, was a stucco made of chalk and crushed tile or kindred substances.

In the groping for adequate protection against the action of water, the pipes were sometimes lined with resinous pine.

In searching for the beginnings of cast-iron pipe, it has seemed surprising that a public demand, which has reached, for purposes of *water supply*, at least 500,000 tons of cast-iron pipe annually, and for gas distribution, not less than 100,000 tons, should have a history so shrouded in obscurity; we might say, like the excavations in King's Chapel burying ground, to which Dr. Green alludes.

The water supply system of the United States aggregates a length of 50,000 miles of cast-iron pipe, and a value of $600,000,000, embraced in 2,000 cities and towns, of which it will be interesting, perhaps, to specify that the daily supply of Chicago is about 250,000,000 gallons, that of Philadelphia about 200,000,000: New York 190,000,000. In my researches in this direction I found about the largest supply per capita is in the city of Alleghany, about 250 gallons; in Buffalo, 186 gallons. London comes down to the consumption of 40 gallons per capita, and the lowest quantity of the present period, I find recorded, is in the city of Howrah, India, where, with a population of 125,000, the supply is 1,250,000, or ten gallons per head. At the end of the 17th century, however, the supply to the city of Paris, was about five pints per capita.

BREECHES PIPE.

DISCUSSION.

Mr. Noyes. Mr. Garrett's paper was exceedingly interesting to me from the fact that it presented the inside working and details of a branch of engineering work which we as engineers do not get very much of a chance to see. I am always jealous of every opportunity to obtain this information, especially when it comes from men who are personally engaged in the work.

I was particularly interested in the statement of Mr. Garrett that the use of four different kinds of iron is essential to the making of the best pipe. In my early work I took up the various specifications of engineers of repute, thoughtful men, men presumed to know their business, and I studied their specifications, and followed them, making such modifications as seemed wise to me to adapt them to the special work I had in hand. There were some sides of the question I was not then familiar with, but I felt it was safe, in view of the fact that men of such high repute had called for certain conditions in the casting and classes of iron used, to incorporate those conditions in my specifications, and did so. But since those earlier days I had had an opportunity to visit various foundries and to talk with the superintendents, and of late I have modified my specifications somewhat; and yet I find that there is still considerable to study and to learn.

In one form of specifications that is quite generally used, it is carefully provided that the pipe shall be of good gray iron and that no scrap will be used. But if you go to a foundry you will find the scrap pile there and you will see them using it.

Mr. Garrett. I will only say a few words on this matter, because I have repeatedly averred I don't know anything about it. As to the use of scrap iron, I will say that in my visits to the foundry yards, I have never happened to see any scrap except the piles of scrap that resulted from broken pipe.

Mr. Noyes. I refer to commercial scrap; I have seen that at the foundries.

Mr. Garrett. I, myself, have never been aware that any such scrap was ever used in pipe. It may be used, however, and probably Mr. Prince can tell you about that a little more accurately than I can. I know that the pipes that are rejected for technical reasons are broken up, and that the iron recovered from them is put back into the cupola and goes into pipes again; and that has always been

recognized as very good practice, and as not reducing the character of the pipe in any degree. As to other scrap, I know nothing whatever. I have never known that there was any other scrap used in reputable foundries for making pipe.

Mr. Prince. As I stated last night to Mr. Noyes we used almost no outside scrap, that is, commercial scrap. Occasionally we get a car load of large machinery scrap. This is always a high grade of iron, such as is generally used for high grade machinery. This we can use and do use occasionally, although I do not suppose in the last eight years we have averaged more than two car loads of it in a year. It is simply an occasional lot, and of course, so small a quantity cuts no figure really in our work. But aside from that, the scrap which we do use is fully equal to the grade of the iron which goes into the pipes, that is, it is usually 2X iron originally. The ordinary scrap, as I said before, we do not use at all. The scrap which results from pipe is fully equal to the pig iron in every way, because it is simply the first melting of pig iron, and any trouble which might arise from that special mixture would show itself in the pipe. If it results in iron which is brittle, cold short or red short, we are aware of it as soon as the pipe come out. All that pipe is put one side, and is not used except in very limited quantities. We understand the danger of it and of course guard against it in every way, because an excessive amount of that sort going in would result in another lot of bad iron. That may be used possibly to the extent of half of one per cent or one per cent of the mixture, and that, of course, as you see, is so small an amount it can exert no practical effect.

But ordinarily that is only a small part of the scrap. The other scrap comes from pipe which have been rejected on account of blow-holes or sand-holes, or some of these technical defects which the engineers are so particular about. Those pipe are broken up, and they are equal to pig iron in our estimation. They are fully equal to the original pig iron, and in fact better, because they have been tested and found to be a good mixture. And while it is scrap to the extent that it is bad casting, that is, a casting which has been broken up, it is not scrap in the ordinary acceptation of the iron trade, that is, it is not stove plate and grate-bars and all that sort of thing. So we may say that practically the use of scrap, as far as we are concerned, is eliminated. It is for our interest to use nothing

but what will make thoroughly good pipe; and it is hard enough to make pipe which will suit the engineers, even with the best of iron.

The PRESIDENT. How do American pipes compare with the English pipes in strength of casting?

MR. PRINCE. I cannot answer that, Mr. President, for I am not familiar enough with the English results. I will say in regard to the tensile strength, that I have made many tests of pipe which have run from 20,000 to 23,000.

The PRESIDENT. Is the bar test a good test of the strength of pipe?

MR. PRINCE. It is as an auxiliary. I do not consider it a good test apart from the inspector's work. A good inspector, who understands his business thoroughly, can tell what the iron is as he goes over the pipe and inspects it generally. The question of shrinkage and so forth will come in, but he can tell very closely whether the pipe is good or bad. A test bar, while it may be poured from the same mixture, is poured into a different mold, is subject to different conditions, and may not show the same results as are shown in the pipe. As an illustration of that I will cite a recent case where test bars showed a deficient strength, while the pipes themselves, which were rejected and broken up, showed some of the toughest iron I have seen for a long time. They were pipes such as we could usually break with one or two blows of a drop weighing two thousand pounds, and yet the drop would strike them and bound off several times without cracking them, showing that in that case at least the test bar and the pipe were not the same, but that the pipe was much better than the bar.

MR. NOYES. I think in discussion among ourselves last night, you took exception to some special clauses which are frequently put into specifications with regard to the class of iron, and the freedom of the iron from certain substances; perhaps you will say something to the Association with regard to that.

MR. PRINCE. My point there was simply making a little fun of some specifications that are drawn, showing the way that a clause will descend from generation to generation in the specifications. I have an impression that many specifications are made up with mucilage and a pair of scissors, and embrace certain clauses, grammatical errors and all, which have come down from previous years. The clause I spoke of particularly to Mr. Noyes was this one, which I

believe now appears in the Philadelphia specifications, that "it shall be entirely free from uncombined carbon when seen under the microscope, and shall admit of being easily drilled or cut." The very essence of gray iron is to have uncombined carbon in it, so far as I have been able to find from any authority I have questioned, and I have asked a good many. Iron that is free from uncombined carbon is simply white iron, and I never have yet found an inspector who is ready to take pipe made out of white iron. It cannot be cut, it cannot be drilled, and it is about as brittle as glass. The gray iron owes its grayness to carbon which is not in combination. The point was brought up more as showing some peculiarities of the specifications, and with how little care they are sometimes drawn.

The President. What percentage of free carbon would there be in gray iron?

Mr. Prince. That varies, of course, with the grade of iron. The average grade that is used in pipe-making contains from 2.5 to 3.75 per cent. It is largely dependent upon the per cent of silicon present, although it is influenced by the other constituents present in a less degree.

Mr. Garrett. In connection with this subject, I would like to make two or three general remarks. Mr. Noyes spoke of the allusion I made last evening to four different kinds of iron. The four different kinds of iron I had in mind were the peculiar kinds of iron, chosen from different parts of the country, because of the qualities contained in each that are found to combine best in making up the mixture for cast-iron pipe. While the manufacturers may have what they call some manufacturing secrets of their own, which they do not propose to give away, as far as these discussions are concerned, we are very glad to answer your friendly questions. Now, Mr. Prince says that there are two carloads of scrap used in his foundry probably during a year. The out-put of the foundry he has the management of is not less than 40,000 or 50,000 tons a year, 150 to 200 tons a day. Therefore, two carloads of scrap, even if it were pretty bad scrap, would n't cut much of a figure.

Mr. Noyes. I might say, Mr. President, in justice to the foundries which Mr. Prince and Mr. Garrett represent, that I do not know that I have ever seen there the commercial scrap pile; but there are other foundries where I have seen it, and what called my attention especially to the matter, was, that I dislike to put out

specifications containing clauses which ought not to be insisted upon; and if better pipes can be made by the use of scrap iron, or iron which has been worked over, and has thereby become tempered, and works better in connection with the pig iron, as it is claimed by some superintendents it does, I believe, as engineers, we should eliminate from the specifications the requirement that it shall not be used.

Mr. Garrett. I am glad Mr. Prince has touched upon what I said about the regeneration of iron. He told us last night that the kind of scrap they used in small quantities was not such as was objectionable in the making of any pipe, and if there were any objectionable features in the scrap they went out through the slag-hole. Is that right?

Mr. Prince. Pretty nearly right.

Mr. Garrett. Well, will you please make it all right?

Mr. Prince. Well, Mr. President, the point is largely this: The question of the regeneration of iron, spoken of by Mr. Garrett, is a little peculiar, perhaps. Iron of a given composition is not helped at all or changed at all by repeated meltings if it retains the same chemical composition. It is all a question of having the right chemical composition. You have a certain per cent of the iron, and a certain per cent of silicon, of carbon, of sulphur, of maganese and of phosphorus, — those are the elements which make up a good mixture. Now, if iron in the form of scrap, resulting from one or two previous meltings, has an undue percentage of an injurious element in it, or an element which in cases may be injurious, it is simply a question of putting another iron with it which will supply that which is lacking in the mixture, so your result mixture may be of the proper chemical composition. The old belief that iron is improved in itself by repeated meltings I think is almost entirely passing away as the result of the experiment and discussion which has been going on in the foundry world during the last two or three years. The question has been very fully ventilated, and we are settling down now to the view that there is nothing especially unknown or peculiar about iron. If you have iron with a given chemical composition you are pretty sure to get a given physical strength. We are far from knowing all about it yet, but we are still studying very hard. If you take poor iron, iron that is low in certain elements, and mix it with another iron which is rich in those elements, in other words treat it so as to get a mixture which has the right percentages of the various elements which you want, it results in what is known as the regeneration of scrap iron.

I think the point Mr. Garrett had in mind was this, that when iron is used which is coated with rust and dirt, the foreign matters largely go out of the slag-hole, and do not go into the iron.

The PRESIDENT. I have been examining the interiors of large pipes lately, and one pipe will be clean and smooth on the interior, while the next pipe will have concentric rings going all around it, sometimes one-sixteenth of an inch in thickness. Can you tell me the cause of them?

Mr. PRINCE. Probably the giving of the hay-rope which is put on first, or some coil of the rope below the surface which is a little too large, or something of that kind. The pressure of the iron down at the bottom of the mold is a great many pounds and perhaps it pressed the mold in a little.

The PRESIDENT. The rings I speak of have the appearance of running around the pipe, not completely around but perhaps half way.

Mr. PRINCE. Those would be what are technically known as core swells, the result of the core giving a little. If we could make an absolutely solid core, that is if we could take the iron spindle and put the mud on it without any intervention of the hay-rope, then we would have it perfectly solid, and that would make the ideal core. Collapsing spindles have been used in this way. But the trouble with all collapsing spindles we have had in this country (they have been used in England, perhaps with more success) is that they are apt to lose their spring and elasticity after a while and to give trouble from other causes. So that the old way of using a spindle, winding a hay-rope around it and then putting on the two coatings of mud, obtains still in all the larger foundries in this country. But unless that core is made in the most solid and careful manner, it is bound to give and cause a core swell. The core is made an eighth to a sixteenth of an inch larger at the bottom than at the top to allow for that compression.

Mr. GARRETT. Before leaving this question I wish to make one inquiry of Mr. Prince. You speak of the different chemical qualities or different chemical constituents of the iron. Now, the choice of the four different grades of iron used, assuming that there are four, is made for the very purpose of getting the different constituents that go to make up the proper chemical combination for iron pipe, as I understand it. Now am I right in saying, as I think I did in my paper, that we use about one quarter of southern iron, and

that it is not found to be desirable in the eastern foundries to use more than about that proportion of southern iron, as it has component parts that go to destroy the best results? Is that true?

Mr. Prince. Well, that is hardly true, Mr. Garrett.

Mr. Garrett. Well, I want you to tell us the truth about it.

Mr. Prince. It cannot be said that Southern iron tends to destroy the best results. In the first place, the term "Southern" covers a wide range of irons, from very good to very bad. By making the proper selection of Southern iron and using it with the proper Pennsylvania, New Jersey, or Virginia irons, we can obtain some of our most desirable mixtures. But if we don't have the right combination we are bound to get bad results. The Southern irons are good irons in their way; that is, they have certain characteristics which unite with the characteristics of other irons to form excellent mixtures.

Mr. Noyes. On the program for last evening it was arranged that there should be a paper by Mr. Brackett on "Protective coatings for cast-iron pipe." Mr. Brackett is not here to-day, and I do not know whether he will be here to read his paper or not, but as we have practical foundry men of large experience present, I would like to ask a question touching on the subject which might, perhaps, more properly have been discussed after the reading of Mr. Brackett's paper. As Mr. Prince has said, many of our specifications are made up by cutting from other specifications, and doubtless we have been inclined to follow on certain subjects the older engineers of repute, and who, we assume, have formed their opinions from study and experience, forgetting that perhaps they may have taken their ideas from the previous practice and have said that what was good enough in the past was good enough for them. Now in the specifications for cast-iron pipe the process for coating is generally described in detail. I know that in certain foundries where I have been it has been found desirable to depart more or less from the description, and in fact I have been told that it was not followed at all. I believe very strongly that as engineers, or as water works men, we should endeavor to draw our specifications so as to call for just exactly what we want and for what is the best; and I believe that to a certain extent we can work in conjunction with the parties who are to produce the goods our specifications call for so as to get the very best results both in the way of price and in the way of goods. Possibly Mr. Prince would be willing to tell us something with regard to their experience in the coating of cast-iron pipe.

Mr. Prince. I am very sorry Mr. Brackett is not here, because I know he has devoted a good deal of time to this subject, and could give us valuable information in regard to it. I will simply say that the process of Dr. Angus Smith, that is to say, the mixture of coal tar, oil, and one or two other ingredients, is not used at all now. In the first place the coal tar of to-day is very different from the coal tar of fifty years ago. The process of making it is different, and the products from different gas works to-day vary largely in their chemical constituents, depending upon the different processes that are used. Dr. Smith's process called for putting a cold pipe in the heated tar and keeping it there for half an hour until the pipe got thoroughly warm. With our present out-put it would be impossible for us to do that. So we first heat the pipes to the proper temperature and then immerse them for about five minutes in the tar. If we had to let them stay there half an hour before we took them out we could n't begin to get through our day's work. Of course, the pipes are tested to see that they are at the proper temperature before they are put in; then they are dipped and allowed to remain for a few minutes, and then are withdrawn and drained and put on the skids. We use the clear coal tar. I think the mixture of linseed oil amounts to very little, because the warm pipe when it is taken out very soon dries out the oil which is in the mixture, so that while theoretically it gives a good result, practically the oil is all dried out by the warmth of the pipe after taking it from the bath, and you have only what you started with, the coal tar coating. Does that answer your question, Mr. Noyes?

Mr. Noyes. I think it does. There is one other question which possibly some one here can answer, and that is as to the lasting qualities, or rather as to the protective qualities, of the Angus Smith coating as compared with the coatings we get now.

Mr. Garrett. I think that could be proven by the record, if the information were really available, as to whether the pipe was treated with the Angus Smith process.

The President. I want to say that this discussion is extremely interesting, and I dislike to bring it to a close; but there is something due to those members who have prepared papers, and I think in justice to them, we should now close this discussion, and proceed with the other papers.

THE FINANCIAL MANAGEMENT OF WATER WORKS.

BY FREEMAN C. COFFIN, BOSTON, MASS.

Read June 10, 1896.

The questions involved in the financial management of water works are of interest and importance second only to those of successful construction. This paper will deal only with municipal works; they are more open to investigation and study than are those owned by private companies, and their finances are more a matter of public interest.

Shortly after beginning to collect the statistics for this paper, the writer was appointed one of a committee of this Association to report upon certain aspects of the financial condition of Municipal Water Works. I was requested by the chairman of that committee to make some report in connection with this paper. This I have endeavored to do as well as possible with the material available. This has modified the character and scope of the paper, which was at first intended to be a study of statistics of operation, and only incidentally with regard to their bearing on the financial success of the works.

Some questions were raised by a guest of this Association at the annual convention in June, 1894, that were of importance and led directly to the appointment of the committee referred to. The questions were in substance as follows: —

First. Are municipal water works systems self-supporting, or will the annual receipts meet the annual expenditures for maintenance, interest, and depreciation?

Second. Are water rates sometimes lowered to a point that renders the works incapable of producing enough revenue to meet the expenditures?

Third. Is the bonded indebtedness expanded for purposes other than that of legitimate construction?

Fourth. Should not extensions of pipe lines and laying of services and similar construction be classed as maintenance and be paid for from the yearly revenue, such being the policy of private companies?

Fifth. As an inference from the foregoing questions, are water rates generally as high as they should be?

An analysis of these questions is necessary. Some points must be settled and some definitions made before the subject can be intelligently discussed.

At the outset of this study, we are met with the fact that there seems to be no generally accepted system of financial management of water works, or even any well defined and generally accepted principles upon which such a system might be founded. Custom and practice vary in different places, and individual works apparently have no consistent theory of procedure. It is hard, if not impossible, to extract required information on important points from the reports of many works.*

In what follows an endeavor will be made to show the need of a consistent and generally accepted theory of management, and in a tentative and preliminary manner to define the terms or nomenclature of water works management.

MAINTENANCE.

In no branch of the subject are settled principles or careful definitions more needed than here. When a report is studied, there should be a fairly clear understanding of what is included under this head, and a settled agreement as to which items of expense are to be classed as maintenance and which as construction, such as does not now exist.

The greatest confusion and uncertainty seem to arise in the treatment of extensions of pipe lines and services. In some reports a part of the services are charged to maintenance and part to construction; in one case about twenty-five and seventy-five per cent respectively.

It has been claimed that as private companies make a practice of paying for ordinary extensions from current receipts, that properly managed municipal works should do the same. In one respect the management of private is different from that of municipal works. I believe that it is not generally the custom among private works to set aside a yearly sum for the depreciation of the plant, while it is the rule that municipal works do this, or cover the same ground in

* Those works which have adopted the form of statistics approved by this Association are a striking exception to this statement, and it is to be regretted that more do not avail themselves of this excellent form.

their provision of a sinking fund. This is a condition of the charters under which their bonds are issued. An examination of this subject of a sinking fund and the depreciation of plant may serve to clear up somewhat this question of maintenance and construction.

DEPRECIATION AND A SINKING FUND.

If a system adds to its construction account each year and makes no provision for the payment of the principle, or for the depreciation of the plant, it would at some future time find itself loaded with a debt and with a worn-out plant on its hands. If it is to go on with its business of supplying water, it must, on account of the deterioration of its plant or the abandonment of some of the same owing to improvements in machinery and other appurtenances of water works construction, incur large expenditures. Such a course would mean final insolvency or a large and sudden demand on the taxpayers. It is claimed by some that to avoid this result, all *ordinary* extension and construction should be classed as maintenance and be paid from current receipts; that nothing but large or unusual expenditures for construction should be met by the issue of bonds. As it is a general principle that is sought, and as there is no way to definitely draw the line between ordinary and large or unusual construction, a method that leaves to arbitrary judgment the apportionment of such expenditure is unsatisfactory.

When a sum is set aside from the revenue each year that, with its accrued interest, is amply sufficient at the end of the life of the works to rebuild or renew them, all legitimate construction may be paid for by the issue of bonds with the provision that for all such construction is provided a sum to cover its depreciation. In this way the finances of a system are kept in equilibrium. The present is not incurring liabilities for the future to pay, and providing no assets for it to realize upon, nor burdening itself by striving to pay for construction that will benefit the future. Each year or period of years will pay its own bills and leave the future years to do the same. There can hardly be injustice in this if construction is not unwisely undertaken.

This system will never place the works out of debt in the sense of paying up all of the bonds, but the point now made is that it is not necessary to good, solvent, business management to do so if there are always assets on hand equal to the liabilities. This provision for de-

preciation should not be confounded with a sinking fund, although the creation of such a fund usually provides for the former. A sinking fund primarily provides a fund for the payment of the bonds at a certain time. It is not clear whether or not a consideration of the depreciation of the plant originally entered into this provision.

The sinking fund period may or may not be identical with the life of the plant. As a matter of fact, I believe the maturity of the bonds rarely extends beyond thirty years. Two per cent of the cost set aside each year will, with accrued interest at three and one third per cent per annum, meet the total cost in thirty years. I believe that one and one half per cent of the cost paid each year with the interest will amply cover the depreciation. This percentage with interest at three per cent will equal the cost in thirty-seven years; at three and one half per cent in thirty-five years, and this period can hardly be considered excessive for the average life of a well built plant if it is kept in fair repair. This percentage for depreciation (if correct) should be the one used when it is desired to find the total annual expenditure that must be met from the revenues when the works are run on a business basis.

If the annual contribution to the sinking fund is such that the sinking fund will equal the cost of the works in a shorter period than the average life of the plant, the difference is an asset of the system uncovered by liabilities, and the extra amount can well be paid by taxation if necessary. If one and one half per cent is a fair estimate for depreciation, and two per cent is paid into the sinking fund, the value of this asset at the time the bonds are paid is one fourth of their face, or one fourth the cost of the works.

The foregoing is not an argument against paying for extensions or other construction from current funds if possible; that is certainly desirable, but it is not necessary to sound business management or to the solvency of the works to do so, and it may be doubtful if it is good policy to increase water rates for that purpose.

In order to definitely and finally settle the distinction between construction and maintenance we must go back to some fundamental principle. This principle is suggested by the words themselves. Construction implies new work, something created; labor and material applied to the production of something that did not previously exist in that form or place. It would include all expenditure for increasing or improving the plant in order to secure new sources of

revenue; also all renewals of worn-out or superseded parts of the plant. It would not include repairs, care, or minor improvements to existing structures.

Maintenance implies all expense connected with operating and maintaining the works; keeping all parts of the same in good order and condition so far as this can be done by repairs. Repairs would include renewals of minor parts of a structure, but not a renewal of the structure itself; for instance, the replacing of a broken pipe, but not the relaying of a street line.

It includes all expenditure on the plant necessary to keep it in good condition, to meet the demands from its present sources of revenue, but not for enlargements or additions to secure more revenue; nor does it include the renewals of parts that are worn out or superseded; the latter are provided for by the sum set aside for depreciation.

The operation of the above principle would classify some items as follows: —

Maintenance. Salaries of permanent officials and employees; care and repairs of plant; pumping expenses; the expense of the above, with a proper amount for interest and depreciation of the plant, would constitute the total annual expenditure for its operation, and should be met from the annual revenue and not by the sale of bonds.

Construction. New pipe lines; new services; new or additional water supplies; improvements of supplies, such as filtration plants, clearing mud from basins, draining swamps, etc.; new buildings and machinery, reservoirs, and stand-pipes; renewals on account of deterioration or insufficiency. Sound business management does not require that such items as the above should be paid from the current revenue.

REVENUE.

A clear definition of what constitutes the legitimate revenue of a municipal system of water works is of importance equal to that of maintenance. All receipts for water service from private consumers are beyond question part of the revenue. Is the money appropriated by the municipality for water for public buildings, fountains, street sprinkling, etc., and for hydrant service for fire protection, a legitimate part of the revenue? If so, what relation should the amount bear to the total expenditure, in order that it shall be only a fair

return for service rendered, and not an unjust burden laid upon the taxpayers that the rates may be low for the benefit of the consumer? The fact must be recognized that the taxpayers and consumers are not identical.

The answer to the question of the equity of a charge for fire protection, and of the proportion of such charge to the total expenditure may be suggested by an examination of the effects of the provision for such protection upon the cost of construction and maintenance. The provision for adequate fire protection materially increases the cost of construction over that necessary for domestic and manufacturing purposes alone. Although the yearly consumption of water for fire protection is but a small percentage of the total, it must be supplied in large quantities in a short time. This requires that the pipes and machinery shall be of greater capacity and the distributing reservoir larger than for domestic service alone.

The increase of cost may be roughly estimated as follows :—

INCREASE IN COST OF CONSTRUCTION FOR FIRE PROTECTION.

For quantity of supply	0
" quality " "	0
Pumping Machinery	100 per cent.
" Stations	33 " "
Pipe System	100 " "
Reservoir or Standpipe	75 " "

Making an average increase in cost of construction of perhaps 75 per cent.

INCREASE IN COST OF MAINTENANCE.

Care and repairs of Pipe System	100 per cent.
Pumping Expenses	33 " "
Office	0
Interest and depreciation	75 " "

Or an increase in the total annual expenditure of probably 50 to 75 per cent; making the additional expenditure due to provision for fire protection from 33 to 43 per cent of the total. This estimate can hardly be considered excessive. Mr. J. Herbert Shedd, a member of this Association, places the proportion at 50 per cent.* As the

* See discussion of J. R. Freeman's paper on "Fire Streams," in the Journal of N. E. W. W. Association of March, 1890.

benefits arising from this fire protection inure to the taxpayers and not to the water consumers, it is only just that at least the additional expense caused by it should be borne by the former.

Viewing the subject from another standpoint, when the system is owned by a private company, a hydrant rental is usually paid by the municipality and raised by taxation. This rental will probably average not less than thirty dollars per hydrant per annum. A price per hydrant is not a correct measure of the value of fire service unless the number of hydrants is also considered. The piping system would necessarily be of as great capacity (and should be greater) when the hydrants are far apart as when they are near together. Perhaps a more correct basis would be so much per hydrant and so many hydrants per mile of pipe. The present practice is to place hydrants too far apart. Viewed from a financial standpoint this is poor policy, especially where the municipality owns the works. It necessitates the use of long lines of hose, greatly decreasing the efficiency of the works.

Undoubtedly the increased expenditure in construction caused by a generous number of hydrants will increase the real efficiency of the system for fire protection much more than the same expenditure in any other direction. It must be remembered that the ideal system would be one in which the static head and the dynamic head at the nozzle were the same, and the best designed works are those that come nearest to this ideal. It should be the constant endeavor in designing a distribution system to secure a proper efficiency at the nozzle with the least possible static head, ever mindful that the interest and depreciation on the increased cost of construction must not exceed the amount saved in running expenses. The economic ideal of design is that in any contemplated improvement the interest and depreciation shall about equal the saving in operating expenses. Sometimes, unfortunately, all question of permanent economy must give way to a necessity for small first cost.

Suppose a street three thousand feet long with six hydrants placed six hundred feet apart on a six-inch main fed from both ends. Four fire streams of two hundred gallons each are needed at a building about midway between two hydrants. Not less than three hundred feet of hose would be required for each stream. If five more hydrants were placed upon this line, reducing the distance apart to three hundred feet, one hundred and fifty feet of hose would answer

equally as well as three hundred in the first instance. The loss of head by friction in the hose would be reduced thirty-one feet, while the cost of the five hydrants would be about $250. This would be partially offset by the saving of wear in six hundred feet of hose dispensed with; on the other hand, if the size of the pipe were increased to eight inches, and the hydrants remain as at first, the loss of head would be reduced about twenty feet, and the increased cost would be about $650; or by doubling the number of hydrants, thirty-one feet head would be saved at a cost of $250 or less; by increasing the size of the pipe from six to eight inches, twenty feet head would be saved at a cost of $650.

To return to the subject of revenue. In view of the foregoing, if in any system the amount appropriated by the municipality for fire service does not exceed fifty per cent of the total annual expenditure including interest and depreciation, the taxpayers are not contributing more than is just toward the support of the works, considering that to supply the consumers alone but from fifty-seven to sixty-seven per cent of the total would be required, while to give fire protection alone, probably not less than that percentage would be needed. It may also be said that if the amount appropriated for fire protection did not exceed $30 per hydrant, it would not be excessive, although this is not so correct a standard, owing to the great variation in the number of hydrants per mile in different places. This reasoning is based upon the assumption that the fire service is such as would be considered by competent authority an efficient one for the place in question.

WATER FOR PUBLIC PURPOSES.

There is one more legitimate source of revenue: this is for the water used in public buildings for ornamental and drinking fountains, street sprinkling, and for flushing sewers. In regard to the quantity used for these purposes, I will quote as follows from a paper read before the American Society of Civil Engineers in June, 1895, by Mr. Dexter Brackett, a member of this Association: "The quantity of water used for these purposes varies to a great extent in different cities on account of the difference in the method of supply. In some cases no charge is made for water for public purposes, while in others the water is supplied through meters, and the water depart-

ment is paid for all water used. Where no charge is made, the consumption is apt to be excessive. . . . A careful study of the quantity required for different public uses based upon such information as the author has been able to obtain, gives the following requirements for the different purposes: —

	Gallons per capita.
Public Buildings, Schools, and Hospitals	2.30
Street Sprinkling	1.00
Flushing sewers and public urinals	.10
Ornamental and drinking fountains	.25
Fires	.10
Total for public purposes	3.75

"Probably four or five gallons per capita should cover all requirements for public purposes."

In making an estimate for general application it would not be excessive to allow three gallons per capita for all public purposes except fires, and from fifteen to twenty cents per thousand gallons would not be too high a price, as will be shown later in this paper.

It follows then, that there are three main sources of revenue: —

First. Rates paid by all classes of private consumers.

Second. Revenue received for water for public purposes.

Third. Appropriation for fire protection.

If in any system the aggregate receipts from these sources equals or exceeds the total annual expenditure, including interest on the cost and a proper sum for depreciation, the works are self-supporting, and may be said to be run upon business principles, with no discrimination in favor of either consumer or taxpayer.

WATER RATES.

We now come to the question whether water rates as generally levied in municipal works are high enough to render the works self-supporting. The answer to this question may be found, or at least suggested by the application of the principles set forth in this paper. An endeavor is made to do this in the case of a number of works, mostly in New England. Table B gives the results in these works. At this point I will state briefly the plan of tabulation of the sta-

WATER WORKS STATISTICS.

TABLE A.

PUMPING.

NUMBER GIVEN TO COLUMNS:			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
														Population.		Head.	
Date of Report.	List Number.	City or Town.	Total Cost of Works.	Miles of Pipe.	Number of Services.	Average Duty.	Annual Consumption in Gallons.	Pounds of Coal.	Pumping Station Expenses.	Maintenance Exclusive of Interest.	Total Revenue from Rates.	Number of Hydrants.	Appropriation.	Total Inhabitants.	On Pipe Line or Consumers.	Static.	Dynamic.
1893	1	Avon, Mass.	$53,945	5	248	15,750,000	20,300,000	197,000	$1,614	$1,817	$3,681	49	$1,000	1,450	1,000	168	183
1894	2	Geneseo, N. Y.	81,500	12	300	6,600,000	46,800,000	700,000	600	3,218	4,145		2,450	2,700	1,750	100	120
1894	3	Needham, Mass.	142,160	22.06	493		40,959,255	325,159	1,600	2,717	4,552	178	5,000	3,900	2,550	225	245
1893	4	Mansfield, Mass.	79,250	8	343		76,338,900	400,317	1,900	2,100	5,349	88	1,500	3,700	2,800	154	
1894	5	Maynard, Mass.	109,000	7.75	465	25,000,000	37,000,000	250,000	745	1,320	4,230	77	2,000	3,000	2,800	186	206
1894	6	Wellesley, Mass.	229,090	25.30	647	39,600,000	67,923,480	393,541	1,538	4,510	8,514	200	3,300	4,000	3,467	250	278
1893	7	Reading, Mass.	174,800	18.40	600	36,200,000	80,875,000	426,000	2,707	4,149	5,283	103	5,600	4,200	3,600	219	236
1894	8	Turners Falls, Mass.	109,910	9	371		117,736,202	586,138	2,500	4,110	9,202	55	3,000	4,500	3,700		225
1894	9	Middleboro, Mass.	102,464	13.50	673	27,729,407	78,174,000	482,330	2,580	3,925	9,924	99	2,000	6,700	4,000	172	205
1890	10	Ware, Mass.	88,835	8.45	430	33,250,027	58,880,010	360,356	1,593	2,592	5,810	80	1,380	7,315	4,500	221	244
1893	11	Whitman, Mass.	111,318	14	751	15,000,000	69,092,000	675,000	2,000	3,480	7,100	130	2,450	6,000	4,600	146	170
1894	12	Canton, Mass.	188,000	18.54	650		60,851,929	373,050	2,534	3,400	6,287	152		4,700			
1894	13	Andover, Mass.	182,000	23.50	655	56,000,000	117,000,000	515,000	2,500	3,900	8,400	178		6,200	4,800	196	300
1894	14	Marblehead, Mass.	262,553	25.50	1,156	18,400,000	79,428,000	627,723	3,500	4,390	11,500	266		8,200	5,000	168	175
1893	15	Randolph and Holbrook, Mass.	280,000				106,000,000	654,263		6,538	8,930		4,500	5,992	5,700		280
1894	16	Attleboro, Mass.	276,541	28.28	1,000	34,385,136	99,136,440	452,050	1,860	5,191	10,352	170	3,900	8,000	6,500	160	188
1893	17	Natick, Mass.	259,243	29.85	1,486	53,896,985	127,238,184	345,300	2,382	7,477	19,750	161		9,000	6,500	167	175
	18	Dedham, Mass.*	206,317	25	905	32,282,983	110,749,322	477,350		7,558	20,377	131		8,000		146	165
1893	19	Peabody, Mass.	313,500	30	1,625	20,000,000	277,500,000	742,000	2,915	5,751	21,000				10,000		
1893	20	Marlboro, Mass.	294,000	33	2,080	49,400,000	160,600,000	526,000	2,026	6,325	28,000	389		14,000	10,000	190	204
1893	21	Charlottetown, P. E. I.	201,266	18	1,761	27,400,000	125,522,000	585,000	1,680	3,538	12,758	92		13,000	12,000	140	153
1893	22	Woburn, Mass.	571,330	49.25	2,464		337,916,250	1,243,100	6,335	12,630	32,485	313	2,700	14,000	13,300		206
1893	23	Quincy, Mass.	677,000	44.84	1,889	44,476,000	266,264,100	1,018,492	5,068	11,370	32,260	186	4,400	20,000	14,000	205	210
1894	24	Brookline, Mass.	1,204,825	60.2	2,549		555,783,793	1,293,277	11,530	18,000	49,121	383	15,773	15,154	15,000		190†

1894	25	Burlington, Vt.	450,092	34.91	2,835		336,504,725		7,940	31,867	38,225	187	3,330	15,700	15,100	270	316
1893	26	Waltham, Mass.	519,000	45.90	2,920	40,663,230	385,073,400	1,500 600	8,359	28,796	56,940	250	4,043	21,000	20,000	164	190
1894	27	Schenectady, N. Y.	220,000	23.50	2,732		1,742,504,000	4,638,000	15,047	26,750	42 810	242		22,000	21,000	146	203
1893	28	Taunton, Mass.	981,845	69	3,635	50,000,000	387,375,000	920,000	6,799	15,254	48,530	658	6,000	27,000	23,350		150
1893	29	Brockton, Mass.	612,700	48.82	3,650	26,957,683	252,780,531	469,222	2,773	6,912	36,352	421	3,000	30,000	24,000		135
1894	30	Woonsocket, R. I.	555,539	37.80	1,621	50,000,000	206,107,000	834,594	3,440	10,086	30,222	436	13,525	27,000	25,000	241	243
1892	31	Newton, Mass.	1,655,364	105	5,002	63,800,000	463,686,489	1,423,200	6,209	14,887	69,118	704	18,297	29,000	26,500	231	260
1894	32	Salem, Mass.	1,784,396	60	5,960	60,400,000	840,721,052	1,938,330	11,283	32,037	57,920	405		32,000	31,500		133
1894	33	Yonkers, N. Y.	1,297,444	50	3,500	50,000,000	992,000,000	4,017,200	15,590	30,934	98,963	513	15,390	36,000	32,000	196	220
1894	34	New Bedford, Mass.	1,590,121	63.80	7,531	70,000,000	1,810,400,000	2,560,000	13,466	31,122	85,000	585	12,000	45,000	44,150	125	130
1894	35	Lawrence, Mass.	2,151,990	65.24	5,056	104,595,585	1 049,938,320	1,624,900	9,353	31,376	85,863	538		48,500	48,000		185
1893	36	Pawtucket, R. I.	1,674,750	118 50	6,386	110,000,000	1,732,825,000	3,600,000	16,525	43,000	129,561	867	14,920		60,000		275
	37	Lynn, Mass.	2,096,350	120	11,095	99,736,937	1,306,471,699	1,769,550	9,843	38,707	174,937	895	20,000	69,650	66,850	159	161
1893	38	Fall River, Mass.	2,176,641	74	6,138	46,000,000	889,954,187	2,994,880	11,560	44,796	119,264	743	13,500	89,576	81,000		186
1893	39	Cambridge, Mass.	3,525,993	123	12,182	51,000,000	2,127,878,627	3,246,200	14,055	53,000	250,032	834		85,000	85,000	91	93

GRAVITY AND PUMPING.

	40	Plymouth, Mass.	248,214	33	1,543		103,475,400	229,000		5,587	17,830	87		7,500		65	66
	41	Malden, Mass.	742,434	67.6	4,750		400,000,000		8,491	31,619	75,000			24,000			
1893	42	Haverhill, Mass.	826,809	45.8	3,772		1,110,000,000	833,000		10,380	81,980	199		31,000	26,000		

GRAVITY.

1894	43	Hudson, Mass.	115,000	16	751					900	8,350	119	1,000	4,800	3,500		
1894	44	Wallingford, Conn.	184,000	19						2,500	12,000	78			5,000		
1893	45	Westboro, Mass.	165,000	13.25	673					700	8,000	81	810	5,000			
1893	46	Northampton, Mass.	305,345	45.75	2,000					2,692	27,337	231	2,000	16,400	12,000		
1894	47	New London, Conn.	554,864	41.50	2,556		426,941,118			6,944	34,907	193	9,650	14,700	14,500		
1893	48	Fitchburg, Mass.	940,000	55	3,571					23,111	54,500	359		25,000	25,000		
1893	49	Holyoke, Mass.	681,217	49	2,974					4,168	68,694	364	3,000		40,000		
1893	50	Manchester, N. H.**	1,150,000	73	4,169					33,000	90,900	568	12,750	50,000	40,000		
1893	51	St. John, N. B.	1,327,421	62.45	5,160					17,000	91,000				40,775		
1893	52	Springfield, Mass.	1,660,140	64.70	7,000		1,576,000,000			35,000	160,936	691	19,178	50,526	43,600		

NOTE. — Systems are tabulated according to the number of consumers, beginning with the smallest.

* Owned by a Company. † Average head of high and low service. ** Pumping by Water Power.

TABLE B.

	EXPENDITURE.						REVENUE.					RAISED BY TAXATION.				
	8	16	17	18	19	20	9	21	22	23	24	25	10	26	27	28
List Number.	Cost of Annual Maintenance.	Interest on Cost of Work at 4 per cent.	Depreciation, $1\frac{1}{2}$ per cent on Total Cost of Works.	Total Annual Expenditure.	Annual Expenditure per Consumer.	Cost per 1,000 Gallons based upon Total Annual Expenditure.	Revenue from Water Rates.	Revenue from Public Use based on 3 Gals. per Capita and 15 cents per 1,000 Gals.	Total Revenue from public and private Consumers.	Annual Revenue per Consumer.	Revenue per 1,000 Gallons Pumped.	Total.	Number of Hydrants.	Amount per Hydrant.	Per cent of Taxation to Total Expenditure.	Cost of Construction per Consumer.
1	$1,817	$2,158	$809	$4,784	$4 78	$0.236	$3,681	$165	$3,846	$3 84	$0.190	$938	49	$19 10	19.6	$54 00
2	3,218	3,260	1,223	7,701	4 30	.165	4,145	288	4,433	2 53	.094	3,268			42.4	46 30
3	2,717	5,686	2,132	10,535	4 13	.257	4,552	420	4,972	1 95	.122	5,565	178	31 30	52.8	55 40
4	2,100	3,170	1,189	6,459	2 31	.085	5,349	460	5,809	2 07	.076	651	88	7 40	10.1	28 30
5	1,320	4,360	1,635	7,315	2 60	.198	4,230	462	4,692	1 67	.127	2,623	77	32 70	34.5	39 00
6	4,510	9,163	3,438	17,111	4 93	.252	8,514	571	9,085	2 62	.136	8,026	200	40 10	47	66 10
7	4,149	6,992	2,622	13,763	3 82	.169	5,283	594	5,877	1 63	.073	7,886	103	76 50	57.3	48 50
8	4,110	4,396	1,648	10,154	2 75	.086	9,202	607	9,809	2 64	.084	341	55	6 20	3.4	29 70
9	3,925	4,099	1,537	9,561	2 39	.122	9,925	660	10,585	2 60	.136		99			26 60
10	2,592	3,553	1,332	7,477	1 66	.127	5,810	740	6,550	1 45	.111	932	80	11 60	12.5	19 70
11	3,480	4,453	1,670	9,603	2 09	.139	7,100	759	7,859	1 71	.114	1,744	130	13 40	18.2	24 20
12	3,400	7,520	2,820	13,740	2 93	.226	6,287	770	7,057		.116	6,683	152	44 00	48.6	44 80
13	3,900	7,280	2,730	13,910	2 90	.119	8,400	792	9,192	1 91	.079	4,718	178	26 50	34	37 90
14	4,390	10,500	3,938	18,828	3 77	.237	11,500	825	12,325	2 47	.156	6,503	266	24 50	34.6	52 50
15	6,538	11,200	4,200	21,938	4 00	.213	8,930	900	9,830	1 79	.093	12,108			55.4	46 50
16	5,191	11,067	4,148	20,401	3 24	.206	10,352	1,070	11,422	1 76	.115	8,979	170	52 70	44	42 30
17	7,477	10,370	3,888	21,735	3 34	.171	19,750	1,065	20 815	3 20	.164	902	161	5 60	4.1	40 00
18	7,558	8,253	3,095	18,906	2 36	.171	20,377	1,310	21,687		.196		131			29 60
19	5,751	12,540	4,702	22,993	2 29	.083	21,000	1,640	22,640	2 26	.082	353			1	31 35
20	6,325	11,760	4,410	22,495	2 25	.140	28,000	1,650	29,650	2 96	.185		389			29 40
21	3,538	8,050	3,019	14,607	1 22	.117	12,758	2,000	14,758	1 23	.118		92			16 75
22	12,630	22,853	8,570	44,053	3 30	.130	32,485	2,180	34,665	2 60	.102	9,335	313	29 90	21.2	43 00
23	11,371	27,080	10,155	48,606	3 47	.183	32,260	2,310	34,570	2 47	.129	14,036	186	75 60	28.9	48 40
24	18,000	48,193	18,072	84,265	5 62	.151	49,121	2,460	51,581	3 43	.093	32,699	383	85 50	38.8	80 40
25	31,867	18,004	6,751	56,622	3 69	.168	38,225	2,470	40,695	2 70	.121	15,922	187	85 20	28.2	29 90
26	28,796	20,760	7,785	57,341	2 86	.149	56,940	3,300	60,240	3 01	.156		250			25 90
27	26,750	8,800	3,300	38,850	1 85	.223	42,810	3,450	46,260	2 20	.265		242			10 50

28	15,254	39,274	14,727	69,255	2 98	.178	48,530	3,850	52,380	2 24	.135	16,875	658	25 70	24.4	35 40
29	6,912	24,508	9,190	40,610	1 69	.161	36,352	3,930	40,282	1 68	.159	330	421	80	.8	25 50
30	10,086	22,221	8,333	40,640	1 63	.198	30,222	4,125	34,347	1 37	.167	6,293	436	14 40	15.5	22 15
31	14,887	66,215	24,830	105,932	4 00	.229	69,118	4,360	73,478	2 77	.158	31.454	704	44 70	29.7	62 50
32	32,037	71,370	26,765	130,172	4 14	.157	57,920	5,170	63,090	2 00	.075	67,091	405	166 00	51	56 70
33	30,934	51,898	19,462	102,294	3 20	.103	98,963	5,280	104,243	3 27	.105		513			40 50
34	31,122	63,605	23,851	118,578	2 69	.065	85,000	7,290	92,290	2 07	.051	26,288	585	45 00	22.2	36 00
35	31,376	86,079	32,280	149,735	3 08	.143	85,863	7,950	93,813	1 95	.090	55,863	538	103 80	37.4	44 50
36	43,000	66,990	25,121	135,111	2 25	.078	129,561	9,900	139,461	2 32	.081		867			27 90
37	38,707	83,854	31,445	154,006	2 27	.118	174,937	11,150	185,087	2 77	.142					31 40
38	44,796	87,065	32,649	164,510	2 03	.185	119,264	13,350	132,614	1 64	.149	31,896	743	43 00	19.4	26 90
39	53,000	141,040	52,890	246,930	2 91	.116	250,032	14,000	264,032	3 11	.124		834			41 50
	Minimum				1 22	.065	Minimum . . .			1 23	.073	Minimum,		80	.8	10 50
	Average				2 58	.115	Average			2 32	.124	Average .		42 74	28.86	38 41
	Maximum				5 62	.257	Maximum . . .			3 84	.265	Maximum,		166 00	57.3	80 40

GRAVITY AND PUMPING.

40	5,587	9,928	3,723	19,238	2 75	.186	17,830	1,150	18,980	2 71	.184	250	87	2 87	1.3	33 20
41	31,619	29,697	11,136	72,452	3 12	.181	75,000	3,940	78,940		.197		895			31 00
42	10,380	33,072	12,402	55,854	3 15	.051	81,980	4,260	86,240	3 31	.078		199			31 80

GRAVITY.

43	900	4,600	1,725	7,225	2 06		8,350	575	8,925	2 55			119			32 90
44	2,500	7,360	2,760	12,620	2 63		12,600	820	12,820	2 56			78			36 80
45	700	6,600	2,475	9,775	2 44		8,000	656	8,656	2 00		119	81	1 47	1.2	41 30
46	2,692	12,214	4,580	19,486	1 63		27,337	1,970	29,307	2 44			231			25 50
47	6,944	22,194	8,323	37,461	2 58	.088	34,907	2,380	37,287	2 57	.087	174	193	90	.5	38 20
48	23,111	37,600	14,100	74,811	2 99		54,500	4,100	58,600	2 34		16,211	359	45 20	21.7	37 60
49	4,168	27,249	10,218	41,635	1 04		68,694	6,560	75,254	1 88			364			17 00
50	33,000	46,000	17,250	96,255	2 40		90,900	6,560	97,460	2 43			568			28 80
51	17,000	53,097	19,911	90,008	2 21		91,000	6,690	97,690	2 45						32 50
52	35,000	66,406	24,902	126,308	2 94	.080	160,936	7,050	167,986	2 40	.106		691			38 60
	Minimum				1 04		Minimum . . .			1 88		Minimum				17 00
	Average				2 29		Average			2 36		Average				32 92
	Maximum				2 99		Maximum . . .			2 57		Maximum				41 30

tistics presented. There are four tables. A, B, C, and D. Table A is a tabulation of the statistics collected from the works under consideration. I should have gladly presented a longer list. These, however, were all that I could secure in the time that I could devote to it. It is difficult to obtain statistics of even limited range that truly give the facts sought, except by giving much time and labor to the work of collection. I believe that the list of works is fairly representative of systems in general, except of those of the large cities, which are not included.

The items contained in Table A are those that are most important in a study of the financial side of water works management. Tables B, C, and D are based upon the figures given in Table A. Table B being an attempt to place the systems studied upon a similar basis for comparison.

Under the head of maintenance, column No. 8 gives the actual annual cost of maintenance of the works as reported. Column No. 16 gives the annual interest. This interest is not the actual interest paid by the works, but is four per cent on the cost of construction. The actual interest paid would not be a fair basis of comparison, for in some cases the bonds are partially paid, and in some a higher rate is being paid on old bonds. Therefore as a correct basis of comparison, and also to give the true economic cost of operating the works, four per cent on the total cost of construction is used for the interest account.

Column No. 17 gives the sum for depreciation at the rate of one and a half per cent of the cost of construction. This was adopted, instead of the actual amount paid into the sinking fund, for reasons similar to those given in relation to the interest account.

Column No. 18 is the sum of the first three, and is intended to represent the total economic cost of running the works, or the total expenditure necessary to carry on the works and keep them in proper condition.

Under the head of Revenue, column No. 9 gives the actual revenue received from private consumers. Column No. 21 gives the amount that should be paid to the departments for water for public uses on the basis of a use of three gallons per capita and fifteen cents per thousand gallons. Column No. 22 is the sum of the first two, and is intended to represent the total legitimate revenue except that for fire protection. Under the head of taxation, column No. 25 gives

the difference between the sum of the revenue from public and private sources and the total expenditure, and when the latter is larger than the former, represents the amount to be raised by taxation, or the cost for fire protection.

The next two columns give the number of hydrants and the annual cost of each, based upon column No. 25.

Column No. 27 gives the percentage which the amount in column No. 25 or cost of fire protection is of the total expenditure. The last column of this table gives the cost of construction of the system, per consumer, and shows roughly that in those systems that raise the greatest per cent by taxation, the cost of construction per capita is the greatest.

An examination of Table B shows that out of fifty-two systems there are fourteen in which the revenue from private consumers is sufficient to meet the total annual expenditure. There are nineteen in which the sum of this revenue and that figured for public purposes will do the same. There are thirty-three in which the revenue from these two sources does not equal the expenditure, and the balance must be raised by taxation, amounting to from 0.8 to 57.3 per cent of the total. In four systems this exceeds fifty per cent.

These results may be considered an answer to the question "whether or not municipal water works are self-supporting," so far as it can be answered in this paper.

The answer to the question "whether rates are sufficiently high" is also implied in the above.

ADJUSTMENT OF RATES.

If the rates in any system are not satisfactory, being either too high or too low, the problem of their adjustment to the requirements of expenditure is one of which it may not be too much to say that no solution has been advanced that considers the conditions of the problem.

The same may be said of fixing rates for new works. The only method that the writer is cognizant of is that of comparison, and comparison of rates only, and not of conditions as well. To collect the schedules of several systems and construct rates from these without regard to such factors as cost of construction per capita, consumption of water per capita, cost of water per million or thousand

gallons, etc., is not a rational method, and gives no assurance that the revenue will be approximately equal to the requirements; yet many if not all rates are fixed in this way.

It is possible to estimate quite closely the probable expenditure, and in case of existing works this is known. Is there any method by which rates can be adjusted to meet this expenditure? In existing works past experience would be a guide; but in new works there is no such guide. There can hardly be a theory advanced for the adjustment of fixture rates. It is possible that with the sale of water by measurement, rates could be devised that would bear some relation to the revenue required. This would, however, be difficult and uncertain until more data upon the subject is available. It may be that the units of maintenance, revenue, and consumption in the tables may be of some service in this connection.

On Table B, under the head of maintenance, in column No. 19, is given the yearly cost per capita based upon the number of consumers. (By consumers is meant the persons living on the pipe line. This basis is used as being more nearly correct for purposes of comparison than that of the total population.) This annual cost per capita is perhaps the most scientific unit for comparing the yearly economic cost of water works. This unit of cost seems to have no law of relation to the number of consumers. It is, however, largely influenced by the cost of construction per capita, and in a less degree by the consumption of water per capita. The fixed charges of interest and depreciation are approximately seventy-five per cent of the total cost of maintaining water works; therefore the item of first cost is the controlling factor in the yearly expense account.

No certain deductions can be drawn from averages of these tables, but a consideration of the minima, the maxima, and the averages of the different units given may serve as a guide in estimating expenses, revenue, and consumption; they are given with all of the units of the tables.

The minimum of the yearly cost per capita in pumping systems is $1.22; the maximum is $5.62, and the average is $2.58.

Column No. 20 under maintenance in Table B gives the cost per thousand gallons of water based upon the total expenditure and total amount of water pumped. The minimum is $0.065; the average $0.115; and the maximum $0.257. This cost is for total

pumpage, and does not represent the cost of water that can be delivered and registered at the meters of consumers.

Mr. Dexter Brackett, in the paper already referred to, shows that in several systems, after making a liberal allowance for unmetered water, only from fifty to sixty-six per cent of the total pumpage is accounted for at the taps of consumers.

With the exception of the deduction that may be made for "slip" in the pump, which would hardly exceed ten per cent, Mr. Brackett ascribes the discrepancy to leakage from mains and services that does not appear on the surface of the ground. The writer of this paper has recently made a careful investigation of the consumption of water in a system where the recording instruments in use afforded an opportunity to discriminate between the leakage in mains and services and the draft at the taps, by studying the relation of the night flow to that of the day. Omitting the details of the study, the results were that in a section of the system supplied by pumping, a total pumpage of about 300,000 gallons per day was found to be made up of 225,000 gallons of leakage and 75,000 gallons of consumption. This supplied approximately 1,000 persons, or at the rate of 75 gallons per capita. A large portion of the leakage was located on a few streets. It was supposed, previous to the examination, that the draft was due to consumption, as no leakage was apparent on the surface. This is an extreme case, but it is likely that in many cases of supposed excessive consumption, a similar state of things exists.

Incidentally the above suggests the desirability of recording instruments on standpipes and reservoirs, and some means of measuring the draft in gravity systems, so that its amount and distribution throughout the day may be known. I believe more attention should be paid to the matter of leakage from the mains in places of large consumption.

If from various reasons not more than one half or two thirds of the water pumped can be measured to the consumers, the cost of 1,000 gallons delivered will be much higher than the cost of 1,000 gallons pumped. If, as shown by Table B the cost of all the water pumped is from $0.065 to $0.257 per 1,000 gallons and averages 0.115, and the cost delivered at the meter is from one and one half times to twice as great, the actual cost of salable water is in some places higher than the rate charged, unless part of the maintenance account is

charged to fire protection. These points should be considered in any question of rates.

An examination of Table B shows that if the principles suggested in this paper are approximately correct, there are very few works that require more revenue from rates after the proper sum is appropriated for fire protection. I believe, from the study I have been able to make, that with the exception of a few works, the rates are sufficiently high to run the works in the manner that they are now run.

Water rates should not be lowered without first making a careful study of the condition and capacity of the supply, also of the distribution system, and a thorough consideration of the needs of the future, and the possibility of present improvement of the works.

More attention must be given in the future to the quality of the supply. This will require additional expense for construction and maintenance. Sand filtration is now practicable, and should be adopted in the case of inferior supplies. The consumer is entitled to as pure water as can be obtained at any reasonable cost. There are supplies that are good for the greater part of the year, but for a short time at certain seasons are very disagreeable if not injurious. Some provision should be made for good water throughout the year by a temporary supply or temporary filtration, if the cause of the trouble cannot be removed.

Many distribution systems are inadequate to furnish a suitable fire protection. Some are believed to be all right simply because they have not yet had to meet conditions that may arise at any time, and because no intelligent study has been made of their efficiency. Probably the works are few of which it can be said that they need no improvements. Therefore it seems unlikely that rates in general can be lowered, and it may be necessary to raise them to meet expenditures due to the increasing cost of supplying water. The growth of population may meet this demand. But with this increase of population, the cost of procuring for it additional supplies will constantly become greater, as will also that of preserving the purity of present sources.

The Metropolitan supply for Boston and its suburbs is estimated to cost ninety cents per capita per annum for the entire population served. This is in addition to the present cost of supply and distribution. There is this to be said, however, if rates cannot be lowered, or even if they must be raised in some cases, that there is no other

service (unless it be the postal service) in which people receive so much that contributes to the necessities, the conveniences, and the luxury of living from the same expenditure, as they do from a well built, well managed system of public water works.

There are three lines of effort the necessity of which should be emphasized, and to advancement along which the influence of the members of this Association should be directed: —

First. Conserving the quantity of supplies by checking waste in all forms.

Second. Improving the quality of the water.

Third. Rendering thoroughly efficient the distribution systems.

Each of these has its bearing on the finances of the system. The first leads to a reduction of expense, and would sometimes prevent a large expenditure for additional supplies. The second and third tend in the opposite direction, and in some cases might necessitate higher rates.

Tables C and D.

I will briefly call attention to some of the units in these tables: —

Column 29 of Table C gives the consumption per capita based on the total population. Column 30 gives the same based on consumers, or the persons living on the pipe lines. The consumption per capita seems to follow a general law of increase with increasing population.

Diagram No. 1 shows the curve of average consumption per capita, based on the statistics of seventy-five places of from 1,000 to 1,000,000 consumers. The formula of this curve is 40 (total number of consumers, x .001) $^{.14}$.

This curve quite truly represents the average and runs from forty to one hundred and five gallons per capita. None of the other units on the table follow any discoverable law. They are as follows: —

Number of gallons pumped per pound of coal.

Number of gallons pumped one foot high per pound of coal.

Cost per million gallons based on pumping station expenses. Same pumped one foot high.

Cost per million gallons based on total maintenance exclusive of interest. Same pumped one foot high.

Population per mile of pipe and per service.

Annual cost of maintenance exclusive of interest and sinking fund, per inhabitant and per consumer.

TABLE C.

List Number.	CONSUMPTION.				PUMPING.						POPULATION.			
	Consumption in Gallons.	Coal used in Pounds.	Daily Consumption per Capita.		Gallons of Water Pumped per Lb. of Coal.		Cost per Million Gallons based on Pumping Station Expenses.		Cost Based on Total Maintenance per Million Gallons.		Population per Mile of Pipe.		Population per Service.	
			Inhab itants.	Consumers.	Total Head.	1 Ft. High Dynamic.	Total Head.	1 Ft. High Dynamic	Total Head.	1 Ft. High Dynamic	Inhabitants.	Consumers.	Inhabitants.	Consumers.
	5	6	29	30	$31 = \frac{5}{6}$	$32 = 31 \times 15$	$33 = \frac{7}{5}$	$37 = \frac{33}{15}$	$35 = \frac{8}{5}$	$36 = \frac{35}{15}$	$37 = \frac{1\,2}{2}$	$38 = \frac{1\,3}{2}$	$39 = \frac{1\,2}{3}$	$40 = \frac{1\,3}{3}$
1	20,300,000	197,000	38	56	103	18,900	$79 50	$0.433	$89 50	$0 488	290	200	5.85	4.03
2	46,800,000	700,000	48	73.5	67	8,040	12 80	.107	68 70	.572	225	146	9	5.8
3	40,959,255	325,159	29	44.2	126	30,900	39 00	.159	66 30	.271	177	113	7.8	5.2
4	76,338,909	400,317	56.7	74.6	191		24 90		27 90		462	350	10.8	8.2
5	37,000,000	250,000	34	36	147	30,400	20 10	.098	35 70	.173	387	362	6.5	6
6	67,923,000	393,541	47	54	173	48,100	22 60	.082	66 50	.239	158	137	6.2	5.4
7	80,875,000	426,000	53	62	190	44,700	33 40	.142	51 20	.217	228	196	7	6
8	117,736,202	586,138	71.8	87.4	201	45,250	21 20	.094	34 90	.155	500	412	12.1	10
9	78,174,000	482,330	32	54	162	33,300	33 00	.161	50 30	.245	496	296	10	6
10	58,880,010	360,356	22.1	36	163	39,772	27 10	.111	44 00	.181	865	532	17	10.5
11	69,092,000	675,000	32	41	102	17,400	29 00	.170	50 30	.295	428	328	7.9	6.1
12	60,851,929	373,050	36.5		164		41 60		55 90		254		7.2	
13	117,000,000	515,000	52	67	227	68,100	21 40	.071	33 30	.111	262	204	9.5	7.3
14	79,428,000	627,720	27	44	126.5	22,200	44 10	.252	55 40	.317	322	196	7.1	4.3
15	106,000,000	654,263	49	51	162	45,400			61 60	.220				
16	99,136,440	452,050	34	42	219	41,250	18 75	.100	52 40	.278	283	230	8	6.5
17	127,238,184	345,300	38.7	53.7	368	64,400	18 70	.107	58 75	.336	300	218	6.1	4.4
18	110,749,322	477,350	38		232	38,300			68 30	.414	320		8.9	
19	277,500,000	742,000		76	374		10 50		20 80			333		6.15
20	160,600,000	526,000	31	44	306	62,200	12 60	.062	39 40	.193	425	303	6.7	4.8
21	125,522,000	585,000	26	29	215	32,900	13 40	.087	28 20	.184	723	677	7.4	6.8
22	337,916,250	1,243,100	66	69.5	272	56,200	18 70	.091	37 50	.181	284	274	5.7	5.5
23	266,264,000	1,048,492	36.5	52	254	53,400	19 00	.091	42 70	.203	446	312	10.6	7.4
24	555,783,793	1,293,277	103.5	104 5	430	81,600	20 80	.11	32 40	.171	252	249	5.9	5.9
25	336,504,725		58.7	61			23 60	.075	95 00	.300	452	434	5.5	5.3
26	385,073,000	1,500,600	50	53	257	48,800	21 70	.114	74 80	.394	458	436	7.2	6 9
27	1,742,504,000	4,638,000	218	227	377	76,500	8 65	.043	15 35	.076	938	894	8.1	7.7

28	387,375,000	920,000	40	46	422	63,300	17 55	.117	39 50	.263	392	338	7.4	6.4
29	252,780,531	469,222	23.2	29	540	73,000	11 00	.082	27 30	.203	615	492	8.2	6.6
30	206,107,000	834,594	21	23	247	60,000	16 70	.069	48 90	.201	715	662	16.6	15.4
31	463,686,000	1,423,200	47	48	326	84,700	13 40	.052	32 10	.124	257	252	5.4	5.3
32	840,721,052	1,938,330	71.8	73.1	434	57,600	13 40	.100	38 10	.297	534	526	5.4	5.3
33	992,000,000	4,017,200	76	85	248	54,700	15 70	.072	31 25	.142	720	642	10.3	9.2
34	1,810,400,000	2,560,000	110	112	707	92,000	7 44	.057	17 20	.132	705	692	6	5.9
35	1,049,938,320	1,624,900	59.4		648	120,000	8 90	.048	29 90	.162	744		9.6	
36	1,732,825,000	3,600,000		79	482	132,550	9 53	.035	24 80	.091		506		9.4
37	1,306,471,699	1,769,550	52	54	740	110,000	7 53	.467	29 70	.185	580	556	5	
38	889,954,000	2,994,880	27	30	297	55,200	13 00	.07	50 30	.275	1,210	1,090	14.5	13.2
39	2,127,878,600	3,246,200	69	69	656	61,000	6 60	.071	24 85	.267	690	690	7	7
	Minimum . . .		21	23	67	8,040	6 60	.043	15 35	.076	158	113	5	4.03
	Average . . .		52.02	62.30	299	56,344	21 00	.118	44 90	.238	475	411	8.32	6.9
	Maximum . . .		218	227	740	132,550	79 50	.467	89 50	.572	1,210	1,090	17	15.4
	GRAVITY AND PUMPING.													
40	103,475,400	229,000	38						$54 00		227		4.9	
41	400,000,000		46						79 20		355		5.1	
42	1,110,000,000	833,000	98	117					9 36		677	567	8.2	6.9
	GRAVITY.													
43											300	217	6.4	4.8
44												263		
45											377			7.4
46											359	262	8.2	6
47	426,941,118		79	81					16 30		352	350	5.8	5.7
48											455	455	7	7
49												817		13.5
50											685	548	12	9.6
51												665		7.9
52	1,576,000,000		85	100					22 20		785	665	7.2	6.1
	Minimum . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	300	217	5.8	4.8
	Average . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	473	472	7.75	7.56
	Maximum . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	785	817	12	13.5

TABLE D.

List Number.	MAINTENANCE. Annual Cost of Maintenance.	Population. Inhabitants.	Population. Consumers.	Annual Cost of Maintenance. Per Inhabitants.	Annual Cost of Maintenance. Per Consumers.	Annual Cost of Maintenance. Per Cent of First Cost.	REVENUE. Annual Revenue from Rates.	Annual Appropriation.	Total Revenue.	Revenue Per Inhabitant. From Rates.	Revenue Per Inhabitant. Total Revenue.	Revenue Per Consumer. From Rates.	Revenue Per Consumer. Total Revenue.	Revenue Per Service from Rates.	Revenue Per Million Gallons from Rates.
	8	12	13	$41 = \frac{8}{12}$	$42 = \frac{8}{13}$	$43 = \frac{8}{1}$	9	11	44 = 9+11	$45 = \frac{9}{12}$	$46 = \frac{11}{12}$	$47 = \frac{9}{13}$	$48 = \frac{11}{18}$	$49 = \frac{9}{3}$	$50 = \frac{9}{5}$
1	$1,817	1,450	1,000	$1 25	$1 82	3.37	$3,681	$1,000	$4,681	$2 54	$3 23	$3 68	$4 68	$14 80	$181 50
2	3,218	2,700	1,750	1 19	1 84	3.95	4,145	2,450	6,595	1 53	2 44	2 36	3 78	13 80	88 60
3	2,717	3,900	2,550	70	1 07	1.92	4,552	5,000	9,552	1 17	2 45	1 78	3 75	9 25	111 00
4	2,100	3,700	2,800	58	75	2.65	5,349	1,500	6,849	1 45	1 85	1 91	2 44	15 56	70 00
5	1,320	3,000	2,800	44	47	1.21	4,230	2,000	6,230	1 41	2 07	1 51	2 22	9 10	114 20
6	4,510	4,000	3,467	1 13	1 30	1.98	8,514	3,300	11,814	2 13	2 96	2 46	3 41	13 17	125 50
7	4,149	4,200	3,600	99	1 15	2.37	5,283	5,600	10,883	1 26	2 59	1 47	3 02	8 82	65 30
8	4,110	4,500	3,700	92	1 11	3.75	9,202	3,000	12,202	2 04	2 72	2 48	3 31	24 80	78 00
9	3,925	6,700	4,000	59	98	3.8	9,925	2,000	11,924	1 48	1 78	2 48	2 98	14 75	127 00
10	2,592	7,315	4,500	36	58	2.93	5,810	1,380	7,190	80	99	1 29	1 60	13 50	98 50
11	3,480	6,000	4,600	58	76	3.13	7,100	2,450	9,550	1 18	1 59	1 54	2 07	9 39	102 60
12	3,400	4,700	4,200	73	81	1.81	6,287		6,287	1 34	1 34			9 68	103 00
13	3,900	6,200	4,800	63	81	2.14	8,400		8,400	1 35	1 35	1 75	1 75	12 83	71 80
14	4,340	8,200	5,000	54	88	1.67	11,500		11,500	1 40	1 40	2 30	2 30	9 97	145 00
15	6,538	5,992	5,700	1 10	1 15		8,930	4,500	13,430	1 49	2 25	1 72	2 36		84 30
16	5,191	8,000	6,500	65	80	1.88	10,352	3,900	14,252	1 30	1 78	1 59	2 20	10 32	104 50
17	7,477	9,000	6,500	84	1 15	2.9	19,750		19,750	2 19	2 19	3 04	3 04	13 30	155 00
18	7,558	8,000		95		3.67	20,377		20,377	2 55	2 55			22 50	184 00
19	5,751		10,000		58		21,000		21,000			2 10	2 10	12 92	75 67
20	6,325	14,000	10,000	45	63	2.15	28,000		28,000	2 00	2 00	2 80	2 80	13 45	174 50
21	3,538	13,000	12,000	27	30	1.76	12,758		12,758	98	98	1 06	1 06	7 25	102 00
22	12,630	14,000	13,300	91	95	2.22	32,485	2,700	35,185	2 32	2 51	2 45	2 64	13 15	96 00
23	11,370	20,000	14,000	57	81	1.68	32,260	4,400	36,660	1 61	1 83	2 30	2 62	17 05	121 00
24	18,000	15,154	15,000	1 19	1 20	1.5	49,121	15,773	64,894	3 24		3 27		19 25	88 50
25	31,867	15,700	15,100	2 03	2 11	7.1	38,225	3,330	41,555	2 44	2 64	2 54	2 75	13 50	114 00
26	28,796	21,000	20,000	1 37	1 44	5.54	56,940	4,043	60,983	2 71	2 90	2 84	3 05	19 50	147 80
27	26,750	22,000	21,000	1 21	1 27		42,810		42,810	1 95	1 95	2 04	2 04	15 70	24 60
28	15,254	27,000	23,350	57	66	1.55	48,530	6,000	54,530	1 80	2 02	2 08	2 34	13 36	125 40

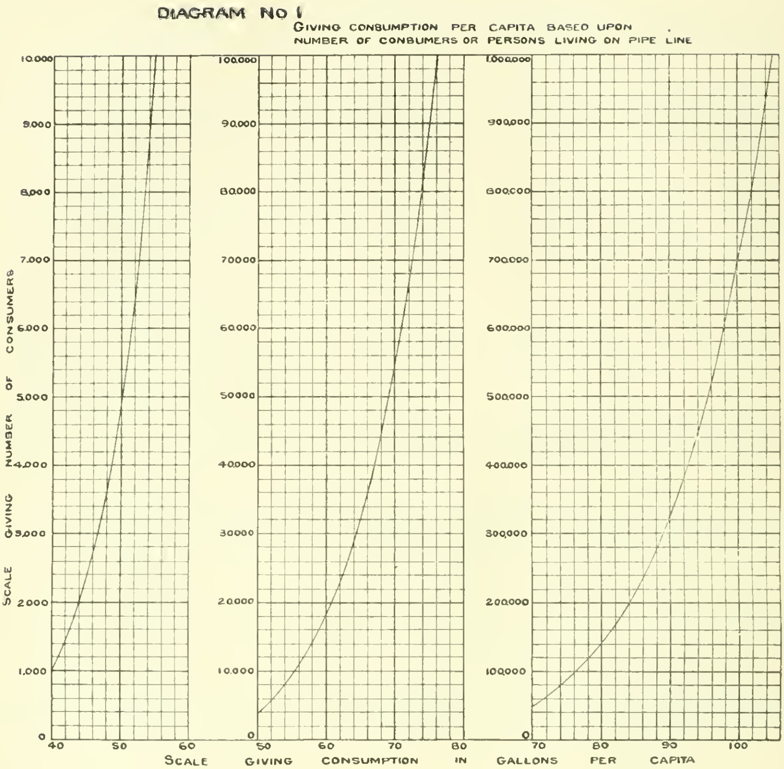
29	6,912	30,000	24,000	23	29	1.13	36,352	3,000	39,352	1 21	1 31	1 51	1 64	9 95	143 70
30	10,086	27,000	25,000	38	41	1.82	30,222	13,525	43,743	1 12	1 62	1 21	1 75	18 65	146 50
31	14,887	27,000	26,500	55	56	.9	69,118	18,297	87,415	2 56	3 24	2 61	3 30	13 80	149 00
32	32,037	32,000	31,500	1 00	1 02	1.79	57,920		57,920	1 81	1 81	1 84	1 84	9 70	68 90
33	30,934	36,000	32,000	86	96	2.38	98,963	15,390	114,353	2 75	3 18	3 09	3 58	28 30	100 00
34	31,122	45,000	44,150	69	71	1.95	85,000	12,000	97,000	1 89	2 15	1 92	2 19	11 20	47 00
35	31,376	48,500	48,000	65	65	1.45	85,863		85,863	1 77	1 77			17 00	81 50
36	43,000		60,000		72	2.57	129,561	14,920	144,481			2 16	2 41	20 30	74 80
37	38,707	69,653	66,850	55	57		174,937	20,000	194,937	2 51	2 79	2 62	2 91	15 76	138 90
38	44,796	89,576	81,000	50	55	2.06	119,264	13,500	132,764	1 33	1 48	1 47	1 64	19 45	134 00
39	53,000	85,000	85,000	62	62	1.5	250,032		250,032	2 95	2 95	2 95	2 95	20 50	117 50
	Minimum			23	29	.9	Minimum			80	98	1 06	1 06	7 25	24 60
	Average			77	91	2.46	Average			1 83	2 13	2 17	2 59	11 98	109 31
	Maximum			2 03	2 11	7.1	Maximum			2 95	3 24	3 68	4 68	28 30	181 50

GRAVITY AND PUMPING.

40	5,587	7,500		75		2.25	17,830		17,830	2 38	2 38			11 50	173 00
41	31,619	24,000		1 32		4.16	75,000		75,000	3 12	3 12			15 80	187 00
42	10,380	31,000	26,000	.33	40	1.26	81,980		81,980	2 64	2 64	3 15	3 15	21 70	73 70

GRAVITY.

43	900	4,800	3,500	19	26	.78	8,350	1,000	9,350	1 74	1 95	2 38	2 67	11 05	
44	2,500		5,000		50	1.36	12,000		12,000			2 40	2 40		
45	700	5,000		14		.42	8,000	810	8,810	1 60	1 76			11 90	
46	2,692	16,400	12,000	16	22	.85	27,337	2,000	29,337	1 67	1 79	2 27	2 44	13 60	
47	6,944	14,700	14,500	47	48	1.25	34,907	9,650	44,557	2 37	3 03	2 40	3 07	13 70	82 00
48	23,111	25,000	25,000	93	93	2.46	54,500		54,500	2 16	2 16	2 16	2 16	15 10	
49	4,168		40,000		10	.81	68,430	3,000	71,694			1 71	1 79	23 00	
50	33,000	50,000	40,000	66	83	2.87	90,900	12,750	103,650	1 81	2 07	2 27	2 59	21 80	
51	17,000		40,775		42	1.28	91,000		91,000			2 23	2 23	17 60	
52	35,000	50,526	43,000	64	82	2.1	160,936	19,178	180,114	3 19	3 56	3 75	4 19	23 00	102 00
	Minimum			14	10	.42	Minimum			1 60	1 76	1 71	1 79	11 05	
	Average			.455	.506	1.42	Average			2 08	2 33	2 40	2 62	16 75	
	Maximum			93	93	2.87	Maximum			3 19	3 56	3 75	4 19	23 00	



Annual revenue per inhabitant based on receipts from rates, also on total receipts including appropriation. The same per consumer.

Revenue per million gallons based upon receipts from rates. The same per service.

The table gives the results for three classes of works: Pumping, Gravity and Pumping combined, and Gravity alone. These tables were computed with the slide rule, and in some cases the last figure may not be correct.

In the preparation of this paper and these tables, I have received much assistance and many valuable suggestions from Mr. W. J. Luther, Civil Engineer, a member of this Association; and I wish also to express my obligation to the members of this Association and others who have so kindly furnished the statistics of the works in their charge.

DISCUSSION.

Mr. Whitney. I thought I understood Mr. Coffin to estimate the consumption per capita for public uses at three gallons per day; did I understand him aright?

Mr. Coffin. Yes; I thought that was a small estimate. Mr. Brackett's estimate, including fire consumption, was from four to five gallons. I based it on his estimate wholly.

Mr. Whitney. Judging it from one place with which I am somewhat acquainted, I should say it came nearer six than three. It seemed to me you were using a small figure.

Mr. Coffin. I used that so as to be entirely on the conservative side. I think my figures show that water works systems in New England are not insolvent or in danger of insolvency, and I thought in making this estimate of the proper amount to be credited to the works for public uses, it would be better to be on the conservative side than to strain a point.

Mr. Crandall. I would like to ask Mr. Coffin if he found that it was usually the custom in replacing lines of pipe to charge it to expense or construction. I am frequently instructed to replace a lot of cement pipe with iron pipe and to charge it to current expense. I understood him to say the general custom was to do otherwise.

Mr. Coffin. I did n't say exactly that. I could not say from the statistics I have received just what the general custom is. In some cases extensions are charged to maintenance, and in other cases they are charged to construction. There does not seem to be any rule or principle or any regular custom about it; some works do one way and some another.

Mr. Crandall. There are a great many works replacing cement pipes, and it would seem to be advisable to have some uniformity in the way of keeping the accounts.

Mr. Coffin. I think in some cases renewals were reported as charged to the maintenance account. I think the tendency is to swell the maintenance account by construction rather than to swell the construction account by items which should be charged to maintenance. It seems to me that there should be some definite rule about it which should be followed. Of course, in any particular place they could pay for whatever construction they chose out of their current receipts, but as a matter of bookkeeping it should be definitely

stated, and there should be an agreement, and it should be understood what constituted maintenance and what construction. That was the point I was trying to make. It is very indefinite at present.

The President. Did you state that the average cost was eleven and one half cents per thousand gallons?

Mr. Coffin. The average cost of water recorded at the pumps, based on the interest on the first cost of construction, one and one half per cent for depreciation, and the cost of running expenses was eleven and one half cents. The consumption of water is generally based on the amount of water the pumps record.

The President. The measurement of the pumps?

Mr. Coffin. Yes; but in the ordinary running of the pumps there is a great deal more slip than there would be in running a pump on a test. In running a pump on a test, the length of a stroke is noted and everything of that kind; but in figuring for the amount of water consumed, the number of revolutions is taken into consideration and the length of stroke is not. It might be that there would be a loss of ten per cent between the amount figured from the displacement of the pumps and the actual amount of water passing through the pipes.

The President. You take into account the cost of distribution?

Mr. Coffin. Yes, sir; everything up to the time of delivery to the consumer. The point I was making was that on Mr. Brackett's figures, backed up, of course, by the experience of most of us, no such amount as is registered at the pumps could be registered at consumers' meters. Mr. Brackett, if I am not mistaken, sets the figure in several places for the amount which can be registered at the meters at from fifty to sixty per cent of the amount of pumpage.

Mr. Crandall. I would like to ask Mr. Coffin if he has ascertained whether in these places where they speak about the small proportion of the pumped water being accounted for, they know how much water is used in watering-troughs and fountains, and for public purposes, or whether that is estimated. I have always thought that that was where the water went rather than through leaks in the mains.

Mr. Coffin. What I said on that part of the subject was taken entirely from Mr. Brackett's paper. He made a very careful study, as I understand it, of the matter in the number of places, and endeavored to take into consideration everything that was going on, and in places where the water was metered to quite an extent; and there is no doubt he has given us the best thing we have of the kind.

I agree with Mr. Crandall that there is a great deal of water wasted at the drinking fountains and watering-troughs. I have seen cases, and have protested against it, where there was probably ten times as much water running in and out as there was any chance of using at all.

Mr. Fuller. I would say that at Wellesley, where all our services are metered, we find that the metered water amounts to about fifty per cent of what we estimate is pumped. I have no doubt myself that there is some leakage in the pipes, and I have been using my influence in endeavoring to have the system tested. I believe that there is more water running to waste through leaks in the pipes than we are aware of. I know at Arlington, after the high service was completed, we carefully tested the whole system, and we found some quite serious leaks which I don't think would have been discovered if we had n't made the test; and as the result of it the apparent consumption was a good deal reduced. I am inclined to think it would be a good plan if works were thoroughly tested every few years; and I believe if that were done a large amount of water would be saved.

The President. Have you in mind, Mr. Fuller, any method of making such a test as you suggest?

Mr. Fuller. The method we have adopted in several instances has been, first, to go over the system with a small testing pump, which, perhaps, would cost, fitted up, thirty dollars. That will give an idea of whether the pipes are tight or not. By shutting off the system into as small sections as possible, and attaching the pump to a hydrant, it can very soon be ascertained whether a section is tight or not, by the capacity of the small pump. If it is, that is all that needs to be done to that section. If it is apparently not tight it is necessary to use a steamer, or some large pump, that will throw more water; and by running that up to a certain speed, of course, if the pipes are reasonably tight, or the leakage is only small, the pressure will increase, and if there is any large leak or any crack in the pipe, the pressure will probably break the cracked pipe, and it will show on the surface. I think this is something which ought to be done to every new system, and I think it would be a benefit to old systems to test them in the same way.

The President. I remember Mr. Jones, who was for many years superintendent of the Eastern Division of the Boston supply, bring-

ing into the office one day a hub that had evidently been leaking for a great many years. The water had been escaping so long it had made a sand blast around it, and it had cut such a distance into the hub that it had weakened it so it finally gave way and there was a break. I do not see why it is not possible that this same sort of thing may be going on in a good many places we know nothing about.

Mr. Crandall. The President's anecdote reminds me of something which happened just before I came from Burlington. There was a cave-in on one of the streets, and on digging out I found half of a half-inch brass corporation cock in the hole in the iron where it had originally been placed, and the other half had entirely disappeared, evidently worn away by the action of the water and sand moved by the water. The galvanized iron pipe which led from this brass cock had also been worn off on one side and a hole made through it for a distance of several inches, — a piece cut right out, worn out smoothly.

In relation to the annual laying aside of a certain amount of money for a sinking fund to cover depreciation, I recently heard advanced by an eminent financier the theory that he was not afraid of any debt on which he was able to pay the interest, and considerable was said in favor of having no sinking fund for any public debt. I do not know whether or not that is to be the coming way of providing money for public uses, but it was a very eminent gentleman who was advocating that plan in connection with raising $100,000 for the city of Burlington.

Mr. Coffin. Possibly a short description of the method I employed to discover leakage in the system I spoke of in my paper may be of interest, as the subject has come up, and as the matter is an important one. The town to which I refer has about one thousand inhabitants. It was brought to my attention that there was apparently a very large consumption, that the water in the standpipe went down about as fast in the night as it did in the daytime, and it was thought something must be wrong. I suggested that we have the cards of the telemeter at the standpipe and the pumping cards. I inspected those cards and I found that out of a total pumpage of about 300,000 gallons per day, there was a difference between the twelve hours from six A. M. to six P. M. and the same time at night of about 35,000 gallons only; that is, there were only 35,000 gallons more used out of the standpipe in the twelve day hours than there were in the twelve night hours. This was in the fall, when there was

no great draught for hose purposes and no wasting to prevent freezing at night. That suggested to me a method of finding out what was consumption and what was leakage from the mains and from the services. I considered that under normal conditions seventy-five per cent of the consumption would be in the twelve day hours, and twenty-five per cent in the twelve night hours. If that was the case, then the difference between the normal consumption of the day and night would be fifty per cent. Now, if fifty per cent was that difference, which in that case was observed to be 35,000 gallons, then the total consumption was about 70,000 gallons. Using that as a basis, that there were 75,000 gallons consumed legitimately, that left 225,000 gallons as the leakage. Following this up, our method of locating the leaks in the different streets was to shut off a certain section or let it on, as the case might be — I won't go into the details of that — and watching the card at the standpipe. We shut it all off at first and found there was no leak in the standpipe, and then we let on a section, and one section after another, and figured the leak from the standpipe. The telemeter, of course, gave us the curve of the water going down in the standpipe. We made the test at night, so the pumping did not come in. And following out this method, which I think was approximately correct, we located leaks in several streets and different sections.

The PRESIDENT. Did you dig down in those places?

Mr. COFFIN. That has n't been done yet. It came on cold weather and we could n't do it then, but it will be done this summer. It is going to be quite an expensive job, for we were not able to locate the leaks exactly.

Mr. HATHAWAY. In making the test on a section of pipe, what arrangements were made in regard to house services? How could you control them so as to tell whether the water was going into them or leaking from the main? Was every house service shut off?

Mr. COFFIN. No, sir; there was none of them shut off. We did the testing between eleven o'clock at night and two o'clock in the morning, during which time, of course, the legitimate consumption would be very small, so if we found a large amount of water going into a short street, we would assume it was not due to consumption.

Mr. NOYES. I would like to ask Mr. Coffin if the 75,000 gallons were determined entirely as stated or whether the further testing of the standpipe indicated the same condition?

Mr. COFFIN. Yes, it indicated practically the same thing.

Mr. Fuller. I think it will be interesting to know if any members here are connected with works in which water actually pumped is checked in some way independent of the pump; that is, if there is anything used similar to a Venturi water meter? I have often thought that would be an excellent thing, for I have no doubt pumps give too high a record of pumpage, especially after they have been used some years.

The President. Can any gentlemen answer Mr. Fuller's question?

Mr. Crandall. We made a short experimental test in that direction in Burlington by checking the registration of our pump by the registration of our meter, a number of years ago. That was done for a definite purpose, when certain parties advocated changing the pumps, and others thought the pumps we had could be repaired, and they cut out a line from the pumps to the reservoir, and for some time checked the registration of the pump by the registration of the meter. The strokes of the meter registered a certain number of gallons and the pump record was compared to that. I do not remember now what the comparison showed.

Mr. Coffin. I think there should be a great deal more attention paid on all water works to recording different items, especially of the consumption of water. I think I had returns from ten gravity systems and only two out of the ten returned the consumption of water. I believe every gravity system, and I advise it in my own practice, ought to have a meter of some kind or some form of weir measurement to measure the consumption of water. That is, of course, one of the first points an engineer has to meet, when he is called to investigate a gravity system of water works, and if he does n't know the consumption he does n't have any starting point for his figures. He can scarcely know what to do until he can get some determination of the amount of consumption. So I claim it is just as important a part of water works construction to have some form of measurement of the water, if there is no pump, as any other part, and as perfectly legitimate an item of expense.

The President. In my own experience I have come across some long mains that were perfectly tight. I tested a force main a mile long not a great while ago and found it tight. At the end of that main we had a weir and a large weir-box, and that gave the measure of leakage. But we all know that there are different ways of laying pipes. I have in mind another pipe a mile in length, laid under

inspection, too, which was so poor I never dared let the water on to it with any great velocity; but someone else did at one time, and then just what I had feared happened. On examining the joints we found that on the under side of the pipe they were not leaded in almost every place. I should like to have some gentleman here say a word on that subject. It seems to me it is an important one. There are a number of town supplies where the head is such that there is none to spare, and where it is a matter of great importance to keep every foot of it. And yet, where pipes are laid carelessly there is more or less leakage, which means loss of head at every point. I think this paper is an extremely useful one, for it brings up many just such matters.

Mr. McNally. I think Mr. Bates has been making some experiments lately which it will interest us to hear about.

Mr. Bates. I hardly know to what the gentleman refers. If it is to leakage, I am glad to be able to say I don't think we have any leaky pipes. There are some places in our town where more head is required, and the question which is now agitating us is whether to pump the water or to secure the extra head by constructing a storage basin higher up than where our basin now is. The problem has been referred to an eminent engineer, Mr. Allen, of Worcester, who is working it out, and perhaps I may be able to give you some information with regard to it later.

Mr. McNally. The point I had in mind was that, knowing Mr. Bates had put in a Venturi meter recently, he might have discovered something interesting from it.

The President. How large a meter did you put in?

Mr. Bates. A 16-inch Venturi.

The President. Did you place it near the pumps?

Mr. Bates. We have no pumps; it is a gravity system. I have n't as yet made a sufficient test to prove the tightness of the pipes, but that can be done later on. I have tried the meter in this way: I shut off a part of the system and connected with the upper section of our town, and there was a registration of 13,000 gallons in twelve hours of water supplied to about one thousand people, which was a very low registration. The test was made under very favorable circumstances however, being on a very wet Sunday when there was no sprinkling and nothing to raise the consumption. This was in a farming district. The small amount per capita showed there could not be much leakage on that line.

The PRESIDENT. Wherever I have seen cast-iron pipes open in the street, and I have seen a great many of them, I have always taken pains to look at the joints, and it is surprising how many of them I have found leaking. Often a joint which is apparently perfectly tight will be seen upon a close examination to show a slight leak.

Mr. BATES. I would like to ask if it is customary among water superintendents to have all main pipes tested before covering?

Mr. FULLER. I don't think they can be on new works very well.

The PRESIDENT. I never saw it done myself.

Mr. COFFIN. On new works it cannot be done usually, but it seems to me very desirable. It certainly would show up any small joint leaks. A small leak can go on for a long time unnoticed at the surface, and even large leaks where there are culverts or sewers to carry the water away. I have seen a case where the water from a large leak flowed underground to a culvert 1,000 feet away, and it would not have been noticed except we knew there was a leak and hunted it up. It might, perhaps, in dry weather, but there was at the time nothing to call attention to any special flow of the stream.

CORRESPONDENCE.

Mr. HAZEN. The paper presented is extremely interesting as showing some of the principles which should be taken into account in calculating the cost of delivering water to consumers. While no direct statements upon that point are made, it is implied that the charges to consumers should be only sufficient to meet the actual cost of supplying water after the city has paid, from funds raised by direct taxation, for the value of fire protection. This theory of fixing the rates is extremely common in America and has much to commend it, but I think it will perhaps be worth our while to remember that there are other theories which might be, and often are, taken into account in establishing water rates.

As Mr. Coffin states, "There is no service (unless it be the postal service) in which people receive so much that contributes to the necessities, the convenience, and the luxury of living from the same expenditure, as they do from a well built, well managed system of public Water Works." The price of a commodity is ordinarily limited by two facts: it will not be supplied for less than its cost to the one delivering it, nor can it be sold for more than its value to the purchaser. These two limits may be, and often are, far apart, and

the difference between them, representing profit, is usually divided between the two parties in proportions varying widely with the conditions of business. No one will question that the value of pure water to consumers is ordinarily much greater than its cost to the city, and in the case of private water companies it is regarded as proper and just to charge a price somewhat above the cost of production as a product on the business. When the matter is taken in hand by the city, this profit is often abolished, or rather given to the consumers, on the theory that it is for the best interests of the citizens, to supply water at the lowest possible figure, that is at cost, but we must not forget that a natural, ordinary price, as measured by general conditions of private business, is somewhat higher than this.

It is the latest American fashion, following long established European precedent, for cities to receive compensation for franchises which they grant to private companies. In case of many of the newer contracts made in this country with street car lines, electric light companies, etc., the companies, in addition to their taxes, are required to pay large sums of money into the city treasuries, and these funds are used to help pay the general expenses of the city government. It would be eminently proper for the city to require a water company to make such payments and to use the money for general expenses. Why is it not equally proper and desirable for the city to charge such reasonable price for the water as will turn a substantial profit into the city treasury, to be used for current expenses? Any system of taxation is more or less unequal, and it is perhaps an open question whether revenue raised in this way will not be as fairly distributed among those who ought to contribute to the support of the government, as from any other source; and so long as only a reasonable price for water is charged, which is far below the value of water to the consumers, it is not apparent that injustice is done to any one.

Further, there are many expenses indirectly connected with the supply of water which have to be borne by the city and which, if they are not met from the sale of water, have to be paid for out of the general tax levy. No sooner has a town introduced a system of water supply than there is a demand for sewers involving a heavy expense to the town, directly due to the introduction of the water. Sometime after sewers are constructed the sewage can be allowed to flow into the nearest stream without further expense, but oftentimes the sewage has to be carefully collected, pumped and purified,

or at least clarified, before it can be discharged, and the expense thus incurred not only follows directly the introduction of the water, but is measurably proportional to the amount of water used; and for every gallon of water used or wasted, the city has to pay twice; once for its collection and distribution as water and once for its collection and disposal as sewage.

It has seemed to many of those in charge of European municipal affairs that it was eminently proper to charge a price for water which, in addition to the whole cost of supplying the same, would pay a portion or all of the cost of disposing of it as sewage, and I question if we cannot, with advantage, adopt this idea under American conditions. It is certainly desirable to have as low rates as possible, but I believe, in the long run, the best interests of American cities will be served by securing thoroughly adequate and pure supplies, and by charging rates high enough to pay all the costs connected therewith, either directly or indirectly, and I see no valid reason why, in a country where indirect taxation by tariffs, internal revenue, etc., is as popular as it is in this country, cities should not derive in addition, a moderate profit from the business which they undertake and to which they lend their credit, turning the same into the general funds available for paying expenses, and thereby lowering the tax rate.

Mr. Coffin. It is certainly desirable to examine the subject of the basis of water rates from various standpoints. I do not believe, however, that the principle suggested by Mr. Hazen is a correct one for a basis of rates, or that the theory of charging for water more than its cost, is a proper one when such service is undertaken by the municipality.

In governments that are run for the benefit of the rulers it is consistent to require compensation for franchises of monopolies of public service. Under a democratic form of government when such service is intrusted to private companies it may be the best way in which the public can be compensated for the excess of profit derived from a monopoly.

Public service when undertaken by the people themselves through their municipal government is a form of co-operation, and the service should be performed at cost to those served. There is no good reason for making a profit on one form of service in order that other forms may be done for less than cost.

All forms of service, such as roads, bridges, schools, etc., the

money for which is raised by a general tax levy, are done at cost. It almost seems absurd to speak of profit in connection with them.

The water service differs from these only in the method of collecting a portion of the cost; a part of it (approximately that part due to fire protection) is usually raised by taxation, while the cost of the domestic and manufacturing service is met by rates that are based in some manner upon the quantity used.

The introduction or the maintenance of an adequate supply of pure water should not be discouraged by burdening it with the necessity of producing a profit, whereby the cost of other forms of service, no more necessary or beneficial, may be lessened.

The value of the service to the individual should not enter into the question of price. The value of water may be infinitely great if there is but one source from which to obtain it. Nor can the cost to the individual of obtaining an individual supply be a measure of the price, or form an argument for profits. As well say that because the cost to each man of a private road to market, etc., would be great, that a profit should be made upon road service and used to reduce water rates. In fact, there seems to be no more reason for making a profit on water than on other forms of public service.

The soundness of the argument for basing water rates upon cost is tacitly admitted by Mr. Hazen, for he favors higher rates in order to meet expenses indirectly caused by the supply of water. A sewerage system is cited as an example of such indirect expense. It is certainly true that all expense really caused by a water supply, whether directly or indirectly, should be figured as a part of its cost. The necessity for sewerage, however, cannot be attributed to the introduction of a water supply. Instead of this, such introduction usually renders the need of sewerage less imperative. While a town is supplied with water from wells, sunk in the populated territory, the danger from sewage pollution is great if the influence of drinking water upon disease is as great as it is now supposed to be. As soon, however, as a supply is taken from a pure source outside of the populated district, the danger is greatly lessened, and in many cases properly managed cesspools can safely care for the sewage for some time.

While the introduction of a water supply does not necessitate sewerage, a modern sewerage system does require a water supply, and for this reason the construction of sewers often follows the introduction of water. This fact may give rise to the belief, more or less general, that the need of sewers is caused by water works.

Instead of the cost of sewerage being a legitimate charge upon water works, the sewers are indebted to the latter for a vehicle by which to transport the wastes that really demand the sewerage system, and in strict justice should not only pay for water for flushing purposes, but a portion of the expense of the water supply.

It is certainly desirable that the revenue from water rates should be large enough to bring the water service to the highest degree of purity and efficiency, but I believe it is in every way undesirable to attempt to secure a profit from the service or charge it with any expenses not legitimately its own.

PROCEEDINGS OF THE FIFTEENTH ANNUAL CONVENTION.

LYNN, MASS., JUNE 10, 11, AND 12, 1896.

The fifteenth annual convention was held at Lynn, Mass., June 10, 11, and 12. The headquarters of the Association was at the Hotel Seymour, and the sessions of the Convention were at the hall of the Oxford Club. Meetings were held on the afternoon and evening of June 10, and on the morning and evening of June 11, for the reading and discussion of papers, and the business meeting on the mornings of June 10 and 12.

WEDNESDAY, June 10, 1896.

The Convention was called to order by President FitzGerald, who said:—

"I have to welcome you, ladies and gentlemen, to the fifteenth annual convention of the Association. We have n't Lake Champlain before us, but we have something which perhaps equals it, the beautiful shores of Nahant and the invigorating sea breezes from the ocean. I have now the pleasure of presenting to you His Honor Mayor Bessom of Lynn, who will say a few words to you in the way of welcome."

ADDRESS OF WELCOME BY MAYOR BESSOM.

Mr. President and members of the New England Water Works Association and guests: It gives me great pleasure in behalf of our municipality to welcome you here to-day. I think Lynn ought to feel honored that you have chosen this place for holding your convention. My pleasure at meeting you here is two-fold. I think it may be of some advantage to the members of this Association to know something about Lynn, but I think it will be of greater advantage to the people of our city to become acquainted with the methods of work and the reason for the organization of the New England Water Works Association; and I have no doubt they will derive that infor-

mation through the medium of the press in the full reports of the doings of your Association while you are in this city.

In regard to our city, of course you know it is one of the oldest of the New England communities, having been settled in 1629; and it is to-day one of the objects of the pride of our Commonwealth, and one of the great hives of industry with which not only Massachusetts but the whole of New England is dotted. And we feel particularly proud of our success because it has not been due, perhaps, to natural advantages, but to the industry and the perseverance and the integrity of the people who make up our community. And that perhaps is not something peculiar to Lynn, but it may be said to be characteristic of all of our New England communities, and certainly not less so of Lynn than of any other city.

Lynn, as I have said, was settled in 1629 by people who came here from Salem, which was the first point of permanent settlement in Essex County. I suppose they felt they were a little crowded in Salem, although we might not think so to-day, and so a few of the Salem settlers came over to Lynn and set up a separate community which was known at that time as the Third Plantation. The first line of demarcation between the townships in Essex County was a line from some rock upon the seacoast up through one of the little islands in one of our beautiful lakes, separating at that time the town of Salem from the town of Lynn.

Lynn has gone on from that small beginning, until to-day we claim that we are the largest manufacturing centre of the world. We have here also, at West Lynn, the large electric works, and we have a large number of other interests, so many that one does not realize the number until he looks through the directory. We have a population of sixty-two thousand people, and we think this is a prosperous community and a good one in which to live.

We have also many natural advantages in the way of beautiful scenery, some of which I trust you will be able to see, and I hope when you return to your homes you may carry with you many very pleasant memories of your visit here.

Now, in regard to the Association. The people of the country, and of course that includes the people of Lynn, probably know but very little about the New England Water Works Association, and yet it is one of the most important organizations, I think, that has been formed in recent years. If you did not meet together and have

the opportunity thus afforded for the interchange of your observations and information deduced from your practical experiences, each man would be left to go along in his own way, and to solve by his own experiments his own difficulties in a way he would think best for himself. But by coming together and listening to the papers which are read, you gain the knowledge and experience of all, and each is made the richer; and by each one being made so much the better informed, the better can he serve the community in which he lives and labors, and thereby the communities receive the benefit of your meetings. And therefore I say that I am glad that you are here in Lynn, that our people may become acquainted with you, and that they may know that this matter of providing suitable water for our domestic uses is being kept abreast of every other subject of municipal interest in this latter part of the nineteenth century.

Now, gentlemen, I do not care to detain you, because I know you have your business to transact, and therefore I will close by welcoming you most heartily to the hospitality of our city. I thank you, Mr. Chairman and gentlemen, for your attention. [*Applause.*]

RESPONSE BY PRESIDENT FITZGERALD.

Mr. Mayor: In behalf of the New England Water Works Association, I desire to thank you for your cordial reception, and to assure you that we believe we shall carry away from your beautiful city far more than we bring to it. As you have said, I hope it will be for our mutual benefit; but I think it will be more for our benefit than for yours. The enterprise and the energy of your people have been well-known to us for many years. Ever since that little manufactory was established on the banks of the Saugus River in 1642, and which I suddenly came upon the other day in a trip I was making through your city, the energy and enterprise of your citizens have been well-known to the whole world. Boston may be the hub of the universe, but this is where we look for the centre of our understandings. [*Laughter.*] But if I were to take one to Lynn to show him what seems to me to be the most attractive side of Lynn, I shall not show him her business enterprises nor the evidences of the public spirit of her inhabitants, but I shall call his attention to the wonderful topography of your city, the beautiful outline of the shore, stretching away to Nahant, that beautiful beach, and I shall take him to High Rock,

one hundred and fifty feet above tide, from which such a magnificent view of forest and of sea can be enjoyed. Then I would take him further inland into that beautiful park which with so much enterprise you have recently given to the public. That seems to me to be a particular jewel of which you may well be proud. And I must confess, that when I first made a trip through the Lynn Woods, as they are called, I was amazed. It does not seem possible that so near to Boston there can be such a stretch of beautiful natural woods, with such a variety of outline, such beautiful valleys, and such high hills commanding such magnificent outlooks. Your city certainly owes an eternal debt of gratitude to Mr. Philip Chase for the energy, the courage and the skill with which he got together those pieces of ground forming the Lynn Woods and, with the assistance of other of your noble citizens, secured them forever to the use of your people. I trust, Mr. Mayor, you may be able to attend our meetings and that you will enjoy our papers. Thanking you again, sir, I will ask the Convention to proceed with the regular order of business. [*Applause.*]

ELECTION OF NEW MEMBERS.

The Secretary presented the following list of applicants for membership, with the approval and recommendation of the Executive Committee: —

RESIDENT ACTIVE.

John E. Smith, Superintendent, Andover, Mass.
Emory A. Elsworth, Civil Engineer, Holyoke, Mass.
Frank S. Badger, Assistant Engineer Locks & Canals Co., Lowell, Mass.
D. W. Tenney, Water Commissioner, Methuen, Mass.

NON-RESIDENT ACTIVE.

C. B. Bryant, City Engineer, Martinsville, Va.
John F. Miller, Secretary and Superintendent, East Pittsburg, Pa.
Henry Metcalfe, Water Commissioner, Cold Spring, N. Y.
H. D. C. Richards, Manager Water Works, Conneaut, Ohio.

On motion of Mr. Fuller, the Convention instructed the Secretary to cast one ballot in favor of the candidates, which he did, and they were declared elected members.

On motion of Mr. Crandall the reading of the records of the last meeting was dispensed with.

ADDRESS OF PRESIDENT FITZGERALD.

LYNN, June 10, 1896.

Gentlemen of the New England Water Works Association:

The Fifteenth Annual Convention marks another year in the history of this Association. It is a fitting time to review briefly the perspective of the past, to glance at our present position, and to turn our faces to the future so fast approaching us. To moralize is almost always wearisome, and from this your retiring President will endeavor to refrain; but one can hardly turn the pages of our record backwards without being struck at the steady, persistent progress of the New England Water Works Association. Here is a concise table of membership from the foundation to the present time.

YEARS.	Active Members.	Associate Members.	Honorary Members.	Total Membership.
June 21, 1882 . . .	27	—	—	27
" 1, 1883 . . .	37	6	—	43
" 19, 1884 . . .	48	Fine 9	—	57
1885 . . .	83	44	—	127
1886 . . .	106	47	—	153
1887 . . .	142	51	1	194
June 13, 1888 . . .	181	54	3	238
" 1, 1889 . . .	209	64	4	277
" 3, 1890 . . .	257	73	5	335
" 1, 1891 . . .	281	74	5	360
" 1, 1892 . . .	290	70	5	365
" 1, 1893 . . .	338	69	5	412
" 11, 1894 . . .	365	73	5	443
" 1, 1895 . . .	401	81	5	487
" 1, 1896 . . .	442	82	5	529

From this table it appears that all the classes of membership are growing; none more persistently than the active member. We must not forget that one of the best foundation stones in our edifice is the Associate member. It is to his skill and enterprise that many of the best advances in water works are due. Without the emulation which springs from competition in the useful arts many of the undertakings which are now so easy of accomplishment would fall to the ground. It is to the workshop and the foundry that we turn for the means of accomplishing some of our best inspirations.

As far as numbers are concerned, we may congratulate ourselves upon the upward rise of the membership curve, but it must be borne in mind that it is not from mere increase of membership alone that a society derives its real strength. It is rather in the ever growing number of those who take an active interest in the welfare of the Association, who attend the meetings, who take part in the literary exercises and discussions, and who give freely from their store of knowledge and experience, that the real vital power of an association is felt and its influence established. It is from this standpoint that our work in the past seems to offer the highest encouragement. The meetings have been growing steadily in interest and activity, and while pervaded with the best spirit of goodfellowship there is always visible a strong undercurrent of earnest desire to learn something to keep fully abreast with the progress of the times and to advance the general cause in which we are embarked.

Let us examine for a moment the work which the Association has been engaged upon during the year just closing, for it is from this kind of a survey that we arrive at the clearest idea of our present position.

During the past year papers on the following subjects have been submitted: Electrolysis; Caloric determination of the value of fuel; Water supplies of Lynn, Burlington, Manchester, St. Louis, Waterbury, and Milford. Uniformity of methods in testing water meters; Tests of articles of commerce to be conducted by the Association; The Metropolitan Water Supply of Massachusetts; The sanitary condition of the water supply of Burlington; An electrical pumping plant; Water borne diseases; Description of second-tube well plant at Lowell; Handling fires while changing distribution mains; The friction in several pumping mains; Some notes on the formation of tubercles in iron and steel penstocks; The appearance of Chara Fragilis in the reservoir of a public water supply; Recording pressure gauges; Water filter at the Milford water works, and Anchor ice.

This list of subjects shows the wide range of topics covered by the papers delivered before this Association. It goes without saying, that both the papers and the discussions ensuing have proved valuable contributions to water supply literature.

Our convention at Burlington in September last will not soon be forgotten. It was a particularly enjoyable occasion. The beautiful

sails on Lake Champlain, the picturesque trip through the Ausable Chasm, and the cordial hospitality so freely bestowed cannot soon fade from the memory.

In one of the advancing steps which this Association has quite recently taken, it seems to me we may feel especial pride. On May 20 we met with our sister society, the Boston Society of Civil Engineers, in the Tremont Temple, and after a most enjoyable banquet opened our permanent headquarters in that new building which has just been erected in the very heart of the city. Here we have a large room comfortably furnished and provided with current magazines, tables at which we may read and study, and desks at which we may write; and here we have started a library in which we trust all members will take an interest and will feel it a matter of honor to foster. With the consent of the Executive Committee, a circular has recently been prepared, and it will soon be sent out all over the country asking for contributions of books and pamphlets for our shelves. The library will be devoted to the subject of Water Works in all its various branches, and perhaps before many years the Association may find itself in possession of a valuable collection of water works books. I trust that the new headquarters will prove a convenience to non-resident members as well as to those who live in the city, for here certainly they will find a quiet place in the busy part of the Hub where they can retire for conference or for study.

If we, as an Association, feel a certain satisfaction in reviewing the past and the present, what should be our thoughts as we turn to the future? One of the surest ways of judging the future is by the past, and by this standard it seems to me that the outlook is a cheerful one. It is an almost every-day expression that we hear about us, "The water works question is getting to be an important one," and nothing can be truer. As we look around we find that almost all the large cities in the country are laboring with the gigantic problems connected with the growth of their water works systems, while the smaller cities and towns are either extending their works or combining for mutual benefit, and even the villages are beginning to waken to the advantages of public supplies.

With all this restless activity in our common interest, it does not seem possible that the future has not some marvellous surprises for us, even when our imaginations are stimulated to the utmost.

One of the most important problems that confront the water works

official, is the question of the reckless use or abuse of water. While many excellent papers have been written on the subject of waste, and none abler than those found in our own transactions, much work still remains to be done in this direction. Enormous sums of money are lavished in the extension of supply systems, but in the majority of cases without succeeding in the effort to get ahead of the consumption. Here is indeed a wide field for patient investigation, and particularly for the display of courage, for it is not always a popular task to limit the use of water to legitimate purposes. A great educational work remains to be undertaken, but the reward is surely ready for those who have the talent and energy to bring about reform.

I have already alluded to the activity going on about us in every direction, connected with water supplies. In every development of this kind New England stands well to the front. It is unnecessary for me to allude to many of the grand enterprises now under way under the direction of members of this Association. You are all familiar with the unique system, already under construction, known as the Metropolitan Water Works of Massachusetts. A system which looks far into the future and which unites in one great chain, stretching westward from Boston, Cochituate Lake, and the Sudbury, Assabet, Nashua, Ware, and Swift rivers. Never before was such a far-reaching scheme started with so little opposition and under such harmonious auspices.

On the borders of New England we find that great metropolitan centre, New York, also engaged in works of grand proportions, unequalled, so far, in the history of the world, and these works are largely under the care of members of this Association. Some of the New York work may not be entirely familiar to the present audience, and at the risk of wearying you I will give a brief résumé of the leading features.

The city of New York is fortunate in having such an excellent source of supply as the Croton River. Almost its only drawback is the fact that even when the present works for its full development are completed, the city in a very few years will be obliged to seek an additional source. The watershed is an excellent one, comparatively free from swamps, and containing a very small population. Its area is three hundred and sixty square miles. A dozen years ago, and after the old Croton aqueduct had supplied New York for

nearly half a century, its capacity was overtaxed and it was found almost impossible to meet the daily consumption, which was then about 110,000,000 gallons. The only way in which the city could be saved from an absolute water famine was by throttling the gates at Central Park reservoir and reducing the pressure in the mains.

An extensive scheme of works was at once planned and carried out, and it certainly constitutes the most stupendous system in the nature of water supply that the world has ever seen. A princely sum was at once put at the disposal of the Commission, $50,000,000. Almost the whole of the additions have either been completed or are in process of execution, and we are in a position to judge of their extent and quality.

The chief peculiarity of the new Croton aqueduct, already completed, lies in the fact that it is almost entirely in tunnel. It is practically thirty-three miles long and has cost $20,000,000, or from $90 to $123 per linear foot. It is of horse-shoe section and equivalent to a 14-ft. circle, and has a capacity of 302,467,000 gallons daily. Seven miles are under pressure, a bold innovation, but which has proved successful. The total leakage outwards in this seven miles is about 228,500 gallons daily, although the maximum pressure is 100 feet head of water. The masonry part of the structure terminates at 135th Street, and from this point eight lines of 48-in. pipe, laid side by side, extend to different points of the distribution system.

While the new Croton aqueduct was building, several very large storage basins were constructed upon the watershed, involving many interesting features. The largest one of all, formed by the Cornell dam, was begun about two years ago. It was estimated that by providing 55,000,000,000 gallons storage, the Croton might be developed to the extent of providing 250,000,000 gallons daily. When the new aqueduct was completed in 1891, the consumption of water in New York rose to 165,000,000 gallons daily, and it is now about 200,000,000 daily, so rapidly is the capacity of new works taxed, if wise restrictions are not placed upon the consumers' end of a system. The available amount of water stored, when all the basins are built, is about 75,000,000,000 gallons.

It was stated that $20,000,000 had been expended on the aqueduct; $10,000,000 more have been expended on the watershed. The new Croton dam will cost $5,000,000; the Jerome Park reservoir $5,000,000 more; making $40,000,000, out of the total $50,000,000

appropriated. The new Croton dam at Cornell's is such a magnificent undertaking that it deserves something more than a passing notice. Statistics, however, are wearisome. It may suffice to state that the dam will be the largest ever constructed by the hand of man. It will be 260 feet high and 190 feet thick at the base which is to repose on the rock more than 100 feet below the river. The water at the dam will be 140 feet deep, but the dam has to be built to withstand a head of over 250 feet. Although the dam was begun more than two years ago, yet the foundations are not even laid. The spill-way which is partly cut out of the side hill, and extends up stream at right angles with the face of the dam, is to be 1,000 feet long, or about the same length as the dam itself.

The Jerome Park reservoir, now begun, will undoubtedly be the finest, most elaborate, and most expensive distributing reservoir in the world. It will hold 7½ days' supply. The Central Park reservoir holds 5 days' supply,— making a total of 12½ days' storage inside of the city. I have gone into the description of the New York works at some length, because they form a type on so large a scale of our American practice.

If we look across the water, however, we find that the same activity, in the direction of extension of water supplies, exists there as in our own land. London is now considering several plans which almost excel any on this side of the Atlantic; Liverpool has built the Vyrnwy dam. Hamburg has just completed its magnificent system of filtration; Paris is reaching out for more comprehensive plans, and the same is true of all the other centres of population in the Old World.

Would it not be a fine scheme if we could have, at some future day, a grand review or Congress of Water Works officials, from all over the world? And what more appropriate place for a meeting could be selected than Boston? The inauguration of the Metropolitan system would afford the excuse, and the execution of the plan would be an honor to this Association and a benefit to all mankind.

In conclusion, permit me to thank you for the kind consideration shown me during the past year. Owing to the nature of my engagements, it has not been possible for me to take as active a part in the labors of the Association as I should like to have done, but with the able supervision of the Executive Committee, the Secretary, Treasurer, and Editors, your business has been faithfully administered. To these officers I desire to extend my hearty thanks.

Since the last annual meeting we have lost by death six of our members: John L. Harrington, M. M. Tidd, C. F. Doherty, Horace L. Eaton, Fred I. Chaffee, and James H. Stanwood. Their last earthly work is accomplished, but their example remains as an inspiration and incentive for our own efforts.

REPORT OF THE SECRETARY.

Summary of Statistics relative to Membership for the year ending June 1, 1896.

Active Members.

June 1, 1895. Total active membership		401	
Withdrawals during the year		10	
		391	
Initiations:			
June, 1895	7		
September, 1895	26		
December, 1895	5		
January, 1896	2		
February, 1896	5		
March, 1896	6		
		51	
June 1, 1896. Total active membership			442

Honorary Members.

June 1, 1895. Total honorary membership		5	
" 1, 1896. " " "			5

Associate Members.

June 1, 1895. Total associate membership		81	
Withdrawals during the year		4	
		77	
Initiations:			
September, 1895	3		
December, 1895	2		
		5	
June 1, 1896. Total associate membership			82
June 1, 1896. Total membership			529

A gain for the year of 42.

Summary of Receipts for the year ending June 1, 1896.

Dr.

Received for advertisements	$1,340 00
" initiation	242 00
" annual dues	1,317 00
" Journals	168 00
" electrotypes	33 00
" badges	10 00
	$3,110 00

1895.	*Cr.*	
July 13.	Paid Geo. E. Batchelder, Treasurer	$700 00
Dec. 2.	" "	1,000 00
Dec. 31.	" "	500 00
1896.		
March 24.	Paid Geo. E. Batchelder, Treasurer . . .	300 00
June 1.	" " . . .	550 00
June 4.	" " . . .	60 00
		$3,110 00

On motion of Mr. Rogers, it was voted that the report be received and placed on file.

ANNUAL REPORT OF THE TREASURER.

George E. Batchelder, *in Account with the* New England Water Works Association.

1895.	*Receipts.*	
	Balance on hand as per last report	$2,673 03
July 15.	Received from J. C. Whitney, Secretary	$700 00
Dec. 2.	" " " " "	1,000 00
1896.		
Jan. 1.	" " " " "	500 00
March 21.	" " " " "	300 00
June 1.	" " " " "	550 00
" 5.	" " " " "	60 00
	Total amount received from J. C. Whitney . .	$3,110 00
Feb. 1.	People's Savings Bank interest	20 48
June 1.	Worcester Safe Deposit and Trust Company interest,	35 07
" 8.	City National Bank interest	14 36
	Total amount received from Secretary and interest,	$3,179 91
	Grand Total	$5,852 94

1895.	*Expenditures.*	
Aug. 22.	P. O'Brien & Son, basket of flowers	$10 00
" 24.	Byron I. Cook, expenses attending meetings of Committee	4 50
" 31.	Rockwell & Churchill, programme and circulars for convention	33 25
Sept. 4.	Geo. E. Batchelder, expenses to Springfield . .	2 24
	Amount carried forward	$49 99

		Amount brought forward	$49 99
Sept.	13.	J. C. Whitney, cash expended on account of Association	92 95
"	13.	J. C. Whitney, salary as Secretary to Sept. 1, 1895 .	125 00
"	21.	Bacon & Burpee, report of proceedings of convention at Burlington	116 60
"	25.	F. H. Crandall, cash on account of meeting at Burlington	35 00
"	25.	F. H. Crandall, cash on account of meeting at Burlington	54 96
"	25.	Electro-Light Engraving Company, one engraving diagram	1 14
Oct.	5.	Mercury Publishing Company, printing . . .	8 50
"	5.	Mercury Publishing Company, holding type four months	4 00
"	22.	J. C. Whitney, stamped envelopes for association .	116 70
"	28.	W. H. Richards, salary, travelling expenses, and typewriting	105 47
"		Rockwell & Churchill, printing	53 75
Nov.		The Day Publishing Company, printing September Journal	191 35
"	16.	Electro-Light Engraving Company, printing . .	13 76
Dec.	5.	" " " " " . .	11 63
"	12.	" " " " " . .	2 80
"	24.	Newton *Journal*, printing	13 75
1896.			
Jan.	1.	The Day Publishing Company, printing December Journal	214 12
"	1.	J. C. Whitney, cash paid out and salary to Dec. 1, 1895	153 13
"	4.	W. H. Richards, postage, expenses, and salary to Dec. 1, 1895	88 74
Feb.	26.	Newton *Journal*, printing	5 25
"	28.	F. H. Crandall, cash paid Burlington Photographing and Engraving Company	16 00
March	16.	Bacon & Burpee, reports of winter meeting . .	73 75
"	20.	W. H. Richards, cash paid out and salary to March 1, 1896	98 61
"	20.	J. C. Whitney, cash paid out and salary to March 1, 1896	167 78
April		Newton *Journal*, printing	63 80
March	21.	The Day Publishing Company, publishing March Journal	192 50
May	9.	Noyes & Hazen, office expenses of senior editor, postage, express, etc.	24 00
		Amount carried forward	$2,995 03

		Amount brought forward	$2,095 03
May	13.	W. M. Belcher & Co., one desk and chair	38 50
"	19.	David P. Page, bookcase for Association rooms	65 00
"	21.	W. E. Parker, rent of chairs, etc., for rooms	7 53
June	5.	Electro-Light Engraving Company, engraving diagrams, etc.	15 08
"	5.	J. C. Whitney, cash paid out and salary to June 1, 1896	192 10
"	5.	W. H. Richards, cash paid out and salary to June 1, 1896	97 78
"	6.	Tremont Temple Building, chairs and services for dedication	14 00
"	6.	Cobb & Devlin, 6 oak arm chairs	15 68
"	6.	Fanning Printing Company, printing	3 00
"	8.	The Day Publishing Company, printing June Journal	492 04
"	8.	Boston Society of Engineers, rent to May 31, 1896	50 00
"	8.	Newton *Journal*, printing	27 75
"	8.	W. B. Badger & Co., one eight-foot table for rooms,	35 00
			$3,148 49

Balance on Hand.

People's Savings Bank	$1,052 64
City National Bank	416 74
Safe Deposit and Trust Company	1,235 07
	$2,704 45

During the year, quarters for the Association have been rented in the Tremont Temple Building and furnished at an expense of $175.71, and rent paid to June, 1896, $50, making a total of $225.71 paid outside the ordinary running expenses.

Respectfully submitted,

GEORGE E. BATCHELDER,
Treasurer.

Approved by Finance Committee, { W. McNally. A. W. F. Brown.

On motion of Mr. Chase it was voted to receive the report and place it on file.

At the afternoon session John C. Haskell, Superintendent, Lynn, Mass., read a paper entitled, "How to Secure Pure Water from a Surface Water Supply." The paper was discussed by Messrs. Cleaves, Noyes, Holden, Goodnough, Fuller, Hawes, and President FitzGerald.

Freeman C. Coffin, Civil Engineer, Boston, followed with a paper entitled, "The Financial Management of Water Works." This paper also led to considerable discussion which was participated in by Messrs. Whitney, Crandall, Fuller, Hathaway, Bates, and President FitzGerald.

The entire evening session was occupied by Mr. Jesse Garrett of Philadelphia, assisted by Mr. Prince. Mr. Garrett's subject was "The Making of Cast Iron Pipe," and his paper was illustrated by the stereopticon.

THURSDAY, June 11.

The morning session was called to order promptly at 10 A. M., and certain phases of the subject presented by Mr. Garrett on Wednesday evening were discussed and more fully presented by Mr. Noyes, Mr. Prince, Mr. Garrett, and the President.

The first paper of the morning was read by Lewis E. Hawes, his subject being "Utilizing a Spring as a Source of Water Supply for a Town."

Mr. F. F. Forbes, of Brookline, followed with a short paper on the "Method of Connecting Driven Wells to Suction Main and Manner of Laying Mains and Connecting with Pump." Messrs. Hawes, Whitney, Smith, Hyde, and the President participated in the discussion that followed the reading of the paper, or asked questions of the writer.

At the evening session Mr. George C. Whipple, Biologist of the Boston Water Works, read a paper entitled, "Some Observations on the Relation of Light to the Growth of Diatoms." Mr. Forbes supplemented the paper by a brief discussion.

F. W. Dean discussed the recent specifications for pumping engines for the water works of the city of St. Louis, Mo.

L. M. Hastings, City Engineer, Cambridge, Mass., gave an account of the extension of the Cambridge Water Works, illustrating his description by a series of stereopticon views, and subsequently he answered numerous questions put by Mr. Stearns, Mr. Fuller, Mr. Smith, and the President.

FRIDAY, June 12.

Vice-President Walker occupied the chair.

The Secretary presented the names of the following applicants for membership, duly approved by the Executive Committee: —

RESIDENT ACTIVE.

John N. Jordan, Superintendent, Malden, Mass.
John W. Crawford, Clerk, Water Board, Lowell, Mass.
Stephen S. Hatch, Water Commissioner, So. Norwalk, Conn.
Walter S. Brown, Registrar, Bangor, Me.
Thomas Roden, Superintendent, Arlington, Mass.

NON-RESIDENT ACTIVE.

Francis H. Luce, Superintendent, Woods Haven, N. Y.
A. Robinson, Superintendent, Benicia, California.

ASSOCIATE.

Garlock Packing Co. (Packing), No. 12 Pearl St., Boston, Mass.

On motion of Mr. Chase the Secretary cast the ballot of the Association for the above named candidates for membership, and they were declared elected.

Mr. Coggeshall moved, "That the thanks of the Association be extended to the Lynn Water Board, to the citizens of Lynn, and to all our Lynn friends who, by their various acts, have done so much to make our Fifteenth Annual Convention a success." Adopted.

On motion of Mr. Coggeshall it was also voted, "That the thanks of the Association be extended to the Salem Water Board and the citizens and ladies of Salem for their generous and cordial contribution to our entertainment."

ELECTION OF OFFICERS.

Mr. Stacey, for the committee appointed to nominate officers for the ensuing year, submitted the following report of nominations which was read by the Secretary: —

President. — JOHN C. HASKELL, Superintendent, Lynn, Mass.

Vice-Presidents. — H. T. SPARKS, Superintendent, Bangor, Me.; C. K. WALKER, Superintendent, Manchester, N. H.; F. H. CRANDALL, Superintendent, Burlington, Vt.; HENRY A. COOK, Superintendent, Salem, Mass.; WILLARD KENT, Manager, Narragansett Pier, R. I.; THEODORE H. MCKENZIE, Manager, Southington, Conn.

Secretary. — J. C. WHITNEY, Water Registrar, Newton, Mass.

Treasurer. — G. E. BATCHELDER, Water Registrar, Worcester, Mass.

Senior Editor. — ALLEN HAZEN, Civil Engineer, Boston, Mass.

Junior Editor. — W. H. RICHARDS, Engineer and Superintendent, New London, Conn.

Executive Committee. — H. G. HOLDEN, Superintendent, Nashua, N. H.: R. C. P. COGGESHALL, Superintendent, New Bedford, Mass.; D. N. TOWER, Superintendent, Cohasset, Mass.

Finance Committee. — A. R. HATHAWAY, Water Registrar, Springfield, Mass.; A. W. F. BROWN, Water Registrar, Fitchburg, Mass.; WM. MC-NALLY, Water Registrar, Marlboro, Mass.

On motion of Mr. Thomas of Lowell, the Secretary was directed to cast the ballot of the Association, for the above named nominees, and they were declared elected.

Vice-President Walker then addressed the newly elected President as follows : —

"Before you take this chair I wish to say that I am glad to give it up to you, for I could not give it up to a better man. I shall go away with a good impression of you and of the Water Commissioners and all the gentlemen of Lynn — the ladies I am not acquainted with. [*Laughter.*] I know they are all pretty good looking, but I have not been introduced. I know that I express the opinion of all our members when I say we fully appreciate what you have done for us here, and that we cordially and gladly recognize you as our new President."

Mr. Haskell replied as follows : —

"Members of the New England Water Works Association, I thank you for this unexpected honor which you have conferred upon me. During the ensuing year I shall endeavor, as far as possible, to assist you in your efforts to make our meetings as interesting and instructive as they have been."

PLACE FOR HOLDING NEXT CONVENTION.

MR. THOMAS. The Water Board of Lowell has authorized me to extend an invitation to the Association to hold their next annual convention in Lowell. The Association met there in 1884, in the early days of its history, and the Water Board would be glad to have you come again. I think many of our members would be interested in the Lowell Water Works, inasmuch as we get all our

water now from underground by a system of tube wells, or three different systems. We believe we have got a capacity of, at least, 8,000,000 gallons, and during the greater part of the year we are confident we can supply 12,000,000 gallons a day. It is something quite rare for a New England city to get such a large amount from wells, and something which we did not expect in Lowell when we first started in. I think it would be of interest to our members to inspect our system.

Mr. Walker. I never liked Lowell because they beat Manchester in baseball, but I know if we go there we will be entertained in good shape, and I am heartily in favor of accepting the invitation.

Mr. Coggeshall. I think this is a matter which had better be referred to the Executive Committee, and I will move that it be referred to them with full powers to report at some later meeting.

Mr. Stacey. Invitations to the Association have been rather rare for the last few years. And this now comes as a surprise to me, and a very agreeable surprise, as I have no doubt it will be to every member of the Association. But the motion that has been made is something which I had in mind to make, and for this reason: I think an invitation of this kind, coming from the city of Lowell, or any other of our thriving cities of New England, ought to be considered by a larger gathering of the Association than is present to-day at this meeting. I was about to make the motion, if it had n't already been made, to refer it to a committee, or to lay it on the table until we have a larger gathering so that we could accept the invitation with something of the enthusiasm and unanimity which it deserves. I heartily second the motion to refer to the Executive Committee, knowing that they will handle it properly, and will bring it before one of our large meetings in the winter.

Mr. Coggeshall's motion was adopted.

On motion of Mr. Stacey the Convention adjourned.

LIST OF EXHIBITS

In Charge of Mr. Henry F. Jenks, Pawtucket, R. I.

R. D. Wood & Co., Philadelphia, Pa., "Reduced" and "Cutting-In," special cast-iron water pipe connections.

Walworth Manufacturing Company, Boston, Mass., Hall tapping machine, pipe cutters, etc.

F. J. Dibble, Peabody, Mass., indicating and recording gauges for height and pressure of water.

Crosby Steam Gauge and Valve Company, Boston, steam gauges, pop safety valves, water relief valves, and water pressure recording gauge.

H. Mueller Manufacturing Company, Decatur, Ill., tapping machine and water works brass specialties.

Michigan Brass and Iron Works, Detroit, Mich., valves and hydrants and water works supplies.

A. P. Smith Manufacturing Company, Newark, N. J., pipe tapping machine.

Neptune Meter Company, New York City, water meters.

Pittsburg Meter Company, East Pittsburg, Pa., water meters.

H. R. Worthington, New York City, photographs of pumping machinery and water meter.

Union Water Meter Company, Worcester, Mass., water meters of various types, with brass and rubber pistons. Souvenir Cox's Kutter's pipe computer.

B. C. Smith, New York City, pipe cutting machine.

Hydraulic Construction Company, New York City, photographs and samples of well points and apparatus for subterranean water supply.

Ross Valve Company, Troy, New York, reducing and regulating valves.

The Ashton Valve Company, Boston, steam gauges and hydraulic relief valves for all purposes; boiler pop safety valves.

Dean Steam Pump Company, Holyoke, Mass.

Hersey Manufacturing Company, Boston, Mass., models of water meters.

Thomson Meter Company, Brooklyn, N. Y., water meters.

Taunton Locomotive Manufacturing Company, Taunton, Mass., copper gaskets.

National Meter Company, New York City, water meters.

Garlock Waterproof Packing Company, Boston, Mass., packing.

Rensselaer Manufacturing Company, Troy, N. Y., fire hydrants and valves.

Lead-Lined Iron Pipe Company, Wakefield, Mass., lead-lined iron pipe and fittings.

ATTENDANCE AT THE CONVENTION.

ACTIVE MEMBERS.

Everett L. Abbott, Brookline, Mass.; Frank A. Andrews, Nashua, N. H.; E. W. Bailey, Somerville, Mass.; Chas. H. Baldwin, Boston, Mass.; A. G. Bancroft, Reading, Mass.; L. M. Bancroft, Reading, Mass.; G. E. Batchelder, Worcester, Mass.; Oren B. Bates, Clinton, Mass.; Jos. E. Beals, Middleboro, Mass.; J. F. Bigelow, Marlboro, Mass.; W. R. Billings, Taunton, Mass.; Dexter Brackett, Boston, Mass.; A. W. F. Brown, Fitchburg, Mass.; J. T. Cavanagh, Quincy, Mass.; Geo. F. Chace, Taunton, Mass.; E. J. Chadbourne, Wakefield, Mass.; John C. Chase, Wilmington, N. C.; Robert L. Cochran, Nahant, Mass.; Wm. F. Codd, Nantucket, Mass.; Freeman C. Coffin, Boston, Mass.; R. C. P. Coggeshall, New Bedford, Mass.; Henry A. Cook, Salem, Mass.; F. H. Crandall, Burlington, Vt.; Geo. K. Crandall, New London, Conn.; J. W. Crawford, Lowell, Mass.;

G. E. Crowell, Brattleboro, Vt.; J. M. Davis, Rutland, Vt.; Francis W. Dean, Boston, Mass.; George E. Evans, Boston, Mass.; B. R. Felton, Boston, Mass.; Desmond FitzGerald, Brookline, Mass.; F. F. Forbes, Brookline, Mass.; Z. R. Forbes, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; L. L. Gerry, Stoneham, Mass.; D. H. Gilderson, Bradford, Mass.; F. B. Gleason, Marlboro, Mass.; T. C. Gleason, Ware, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; X. H. Goodnough, Boston, Mass.; Fred. W. Gow, Medford, Mass.; Amos A. Gould, Leicester, Mass.; E. A. W. Hammatt, Boston, Mass.; John C. Haskell, Lynn, Mass.; V. C. Hastings, Concord, N. H.; Louis E. Hawes, Boston, Mass.; S. S. Hatch, So. Norwalk, Conn.; F. W. Hodgdon, Arlington, Mass.; H. G. Holden, Nashua, N. H.; J. A. Huntington, Haverhill, Mass.; H. N. Hyde, Newtonville, Mass.; J. N. Jordan, Malden, Mass.; D. B. Kempton, New Bedford, Mass.; Willard Kent, Narragansett Pier, R. I.; P. Kieran, Fall River, Mass.; Frank C. Kimball, Boston, Mass.; Geo. A. Kimball, Boston, Mass.; Morris Knowles, Boston, Mass.; Jas. W. Locke, Brockton, Mass.; Jos. A. Lockwood, Yonkers, N. Y.; A. E. Martin, So. Framingham, Mass.; W. E. McClintock, Boston, Mass.; Wm. McNally, Marlboro, Mass.; Jas. W. Morse, Natick, Mass.; Chas. F. Murphy, Marlboro, Mass.; Thos. Naylor, Maynard, Mass.; Albert F. Noyes, Boston, Mass.; J. H. Perkin, Watertown, Mass.; Fred G. Perry, Pawtucket, R. I.; Thos. Roden, Arlington, Mass.; Geo. S. Rice, Boston, Mass.; W. H. Richards, New London, Conn.; Henry W. Rogers, Haverhill, Mass.; Daniel Russell, Everett, Mass.; A. H. Salisbury, Lawrence, Mass.; J. D. Shippee, Holliston, Mass.; Melville A. Sinclair, Bangor, Me.; John E. Smith, Andover, Mass.; Sidney Smith, Rutland, Vt.; Geo. A. Stacey, Marlboro, Mass.; Fred. P. Stearns, Boston, Mass.; John C. Sullivan, Holyoke, Mass.; D. A. Sutherland, Lynn, Mass.; Fred. L. Taylor, Brookline, Mass.; Lucian A. Taylor, Boston, Mass.; Jos. G. Tenney, Leominster, Mass.; Robert J. Thomas, Lowell, Mass.; Wm. H. Thomas, Hingham, Mass.; John Thomson, New York City; D. N. Tower, Cohasset, Mass.; D. W. Tenney, Methuen, Mass.; Chas. K. Walker, Manchester, N. H.; E. L. Wallace, Franklin Falls, N. H.; J. Alfred Welch, Methuen, Mass.; Geo. C. Whipple, Brighton, Mass.; John C. Whitney, West Newton, Mass.; Geo. E. Wilde, Menominee, Mich.; Geo. E. Winslow, Waltham, Mass.; E. T. Wiswall, West Newton, Mass.; Timothy Woodruff, Bridgeton, N. J.; W. G. Zick, New York City. Total, 102.

HONORARY MEMBERS.

"Engineering News," by Geo. C. Martin; "Engineering Record," by C. J. Underwood; "Fire and Water," by F. W. Sheppard. Total, 3.

ASSOCIATE MEMBERS.

Allis Company, The Edward P., by Jno. H. Lewis.
Ashton Valve Company. H. O. Hinkson, C. W. Houghton.
Blake Manufacturing Co., The Geo. F., by W. D. Fiske.
Crosby Steam Gage and Valve Company, S. G. Reed.

Dean Steam Pump Company, Chas. P. Dean, A. M. Pierce, F. H. Hayes, J. E. Batchelder.

General Manufacturing Company, by J. B. Cleaver.

Garlock Packing Company, by Jno. D. Lane and Jno. B. Perkins.

Hersey Manufacturing Company, by A. A. Blossom and Samuel Harrison.

Hydraulic Construction Company, The, by Wm. D. H. Washington and B. W. Mitchell.

Michigan Brass and Iron Works, H. H. Kinsey.

Morison, Samuel L.

Mueller Manufacturing Company, H., W. N. Dill.

National Meter Co., J. G. Lufkin.

Norwood Engineering Company, by W. A. Stevenson and H. T. Quint.

Pittsburg Meter Company, by A. G. Holmes.

Rensselaer Manufacturing Company, Fred A. Bates.

Ross Valve Company, by Wm. Ross.

Smith, Anthony P., by W. H. Van Winkle.

Smith, Benjamin C., by Fred A. Smith.

Snow Steam Pump Co., The, J. F. Holloway.

Standard Thermometer Company, F. J. Dibble.

The Sumner & Goodwin Company, by F. J. Sumner.

Thomson Meter Company, E. T. Ivins, S. D. Higley.

Union Meter Company, by J. B. K. Otis, Geo. H. Carr.

Walworth Manufacturing Company, by J. H. Eustis.

Wood & Co., R. D., by Jesse Garrett.

Woodman Company, The George, by H. A. Gorham.

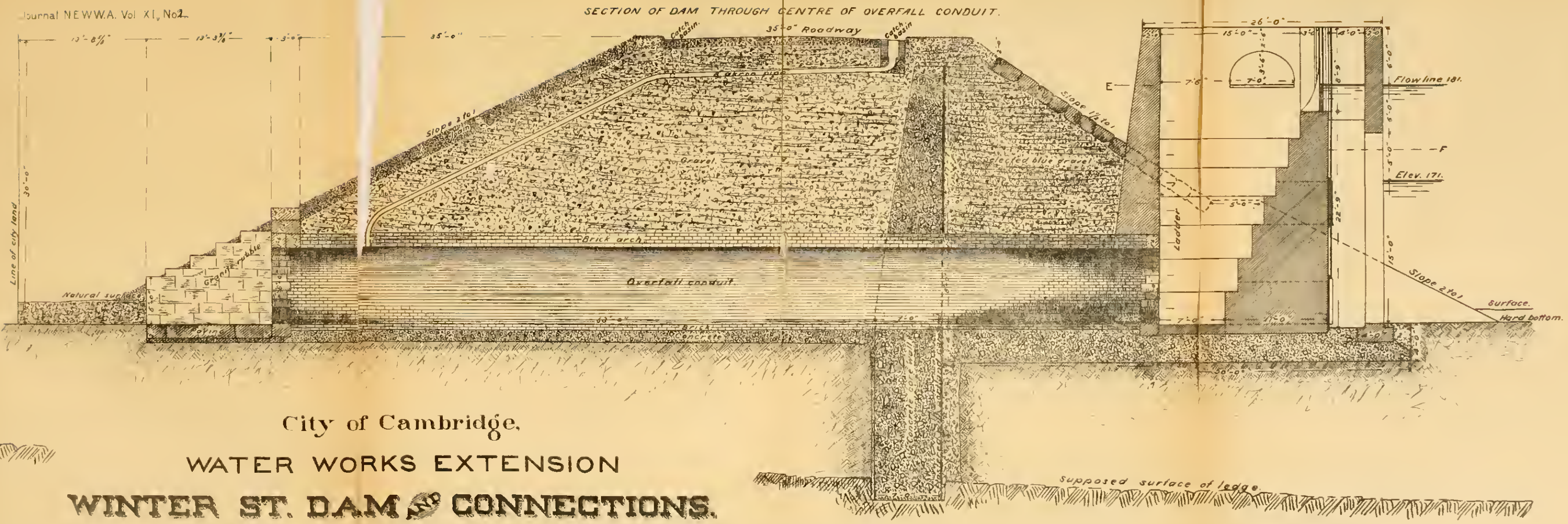
Worthington, H. R., by Geo. B. Ferguson and J. M. Betton.

GUESTS.

Mrs. E. L. Abbott, Brookline, Mass.; Mrs. Chas. H. Baldwin, Boston, Mass.; T. Howard Barnes, Medford, Mass.; Jas. S. Beless, Salt Lake City, Utah; Mrs. Jas. S. Beless, Salt Lake City, Utah; Mrs. A. A. Blossom, Salem, Mass.; Miss Bessie E. Blossom, Salem, Mass.; Mrs. L. M. Bancroft, Reading, Mass.; Jas. S. Beal, Cohasset, Mass.; Mrs. J. E. Beals, Middleboro, Mass.; C. O. Beede, Lynn, Mass.; Mrs. A. H. Coulson, Salem, Mass.; Mrs. E. J. Chadbourne, Wakefield, Mass.; Miss Maud Cole, Andover, Mass.; Mrs. W. F. Codd, Nantucket, Mass.; Mrs. Geo. K. Crandall, New London, Conn.; D. F. Callahan, Marlboro, Mass.; Wm. H. Doty, Yonkers, N. Y.; Thos. E. Dwyer, Wakefield, Mass.; Mrs. Geo. E. Evans, Boston, Mass.; Mrs. F. F. Forbes, Brookline, Mass.; August Fells, Lowell, Mass.; Mrs. L. F. Fuller, Wellesley, Mass.; Mrs. Laura W. Forbes, Brookline, Mass.; J. F. Gleason, Quincy, Mass.; Chas. R. Gow, Boston, Mass.; Miss J. M. Ham, Boston, Mass.; Geo. R. Hall, Marlboro, Mass.; Mrs. Sam'l Harrison, Boston, Mass.; Edward F. Hughes, Boston, Mass.; Mrs. F. H. Hayes, Boston, Mass.; Mrs. H. G. Holden, Nashua, N. H.; W. T. Johnson, Boston, Mass.; S. H. Jones, Lowell, Mass.; Mrs. David B. Kempton, New Bedford, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Wm. B. Littlefield, Lynn, Mass.; Mrs. A. D. Lufkin,

Gloucester, Mass.; Wm. E. Mayberry, Braintree, Mass.; Mrs. J. Merrick, Boston, Mass.; Miss Edna Moffat, Richmond, Va.; Miss Helen Noyes, Newton, Mass.; Thos. P. Nichols, Lynn, Mass.; W. B. Nye, Boston, Mass.; Patrick O'Connor, Brookline, Mass.; H. R. Parker, Lynn, Mass.; Geo. E. Putnam, Lowell, Mass.; H. S. Proctor, Lowell, Mass.; Mrs. C. T. Proctor, Lowell, Mass.; Arthur W. Rayner, Newton, Mass.; Miss Vernie Robinson, Salem, Mass.; Mrs. Daniel Russell, Everett, Mass.; T. H. Rogers, Nashua, N. H.; Mrs. T. H. Rogers, Nashua, N. H.; Edwin W. Snow, Salem, Mass.; Mrs. E. W. Snow, Salem, Mass.; Mrs. Wm. H. Thomas, Hingham, Mass.; Miss Emma Thornton, Auburn, N. Y.; Mrs. M. A. Wallace, Franklin, N. H.; Mrs. Geo. C. Whipple, Newton, Mass.; E. A. Wood, West Newton, Mass.; Mrs. J. A. Welch, Methuen, Mass.; Mrs. Edgar Wordlyston, Salem, Mass.; Mrs. Geo. E. Winslow, Waltham, Mass.; Miss A. E. Winslow, Waltham, Mass. Total, 65.

Journal N.E.W.W.A. Vol XI, No2.



City of Cambridge,

WATER WORKS EXTENSION

WINTER ST. DAM AND CONNECTIONS.

JAN. 14, 1895.

L. M. Hastings
City Engineer.

Journal N.E.W.W.A. Vol XI, No. 2

City of Cambridge,

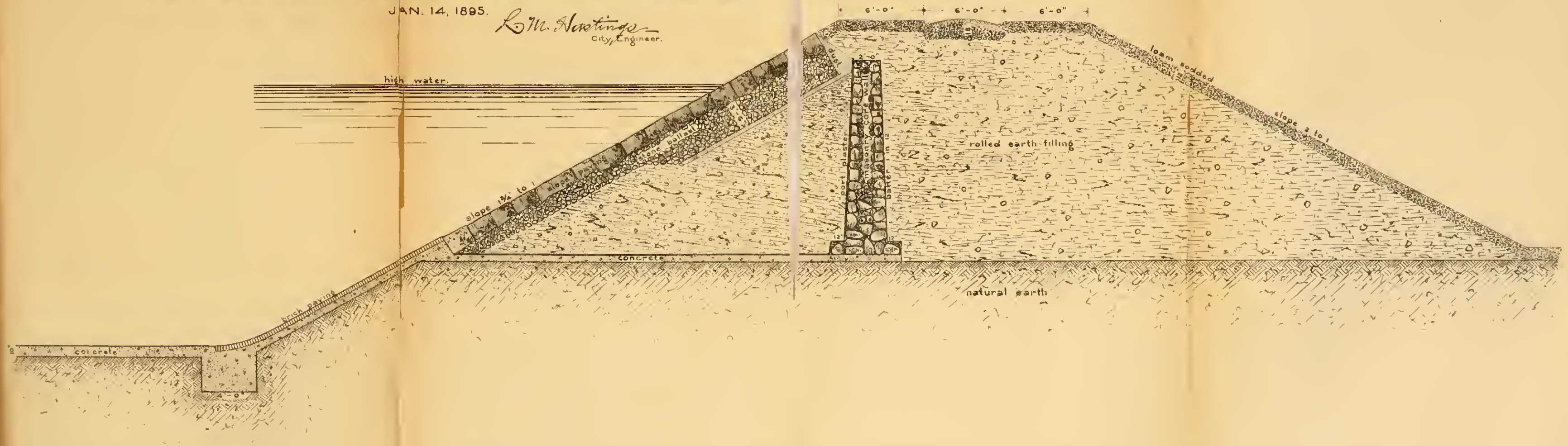
WATER WORKS EXTENSION

WINTER ST. DAM AND CONNECTIONS.

JAN. 14, 1895.

L. M. Hastings
City Engineer.

TYPICAL SECTION OF EMBANKMENT



NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

VOL. XI. DECEMBER, 1896. NO. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE WATER WORKS OF CAMBRIDGE, MASS.

BY L. M. HASTINGS, CITY ENGINEER, CAMBRIDGE.

Read June 1, 1896.

HISTORY.

In order to clearly understand a description of the Cambridge Water Works, a brief glance at its history will be necessary.

The first public water supply was introduced into the city by the "Cambridgeport Aqueduct Company," chartered in 1837, taking water from springs on Prospect Hill, Somerville, and conducting, by means of wooden pipes, the water to the consumers in Cambridge. In 1856 another company was incorporated, called the "Cambridge Water Company," authorized to take water from Fresh Pond, and the surplus water or overflow from Spy and Little ponds, these ponds being situated near the westerly boundary of Cambridge. In 1861 the Cambridge Water Company bought out the original Aqueduct Company, and in turn the entire works were sold, in 1865, to the city of Cambridge for the sum of $291,400. At this time (1865) the population was 29,112. I may add here, that the total amount paid on account of Water Works Construction to December, 1895, has been $4,022,681.92.

Various grants for increasing the supply have been given by the Legislature of this State from time to time, the most important of which was the right granted, in 1884, to take the water of Stony Brook, a tributary of the Charles River, lying in the city of Waltham,

and the towns of Weston, Lincoln, and Lexington. The water from this brook is now the chief reliance of the city, and it is in the development of this supply that the extension of the present system consists, the yield from Fresh Pond now forming a very inconsiderable portion of the Cambridge supply. Cambridge has at present a population of about eighty-four thousand, and had an average daily consumption, in 1895, of 6,000,000 gallons or 71.65 gallons per day per capita.

THE PRESENT SUPPLY AND WORKS.

Water is gathered at the Stony Brook Basin, near its junction with Charles River, — this basin holding about three hundred and fifty million gallons. This dam and basin were constructed in 1887. From here the water is conveyed by a cast-iron pipe conduit, 30 inches in diameter and nearly eight miles long, to Fresh Pond, which stores about four hundred million gallons.

A very curious fact about Fresh Pond is its extremely low elevation. When full, it is but about one foot above the level of mean high tide in Boston Harbor, and it has been pumped so low as to be about on the same elevation as mean low water, or ten feet below high tide level. The mingled waters of Fresh Pond and Stony Brook are now pumped from this low elevation to the present reservoir and standpipe in the city, and so delivered to the consumers through 125.19 miles of water pipes, and 12,681 service connections. A small part of the water is pumped by high service pumps, so as to give a pressure of about sixty pounds per square inch, but the larger portion is pumped to the reservoir, giving about thirty-five pounds per square inch pressure.

The present estimated capacity or available yield of the supply is 7,250,000 gallons daily; 1,250,000 gallons from Fresh Pond, and 6,000,000 gallons from Stony Brook. It will thus be seen that the consumption is close on to the present capacity of the works.

EXTENSION OF THE WATER WORKS.

The large and expensive extensions to the works, now being constructed, are for the purpose of accomplishing three objects: first, increasing the supply; second, increasing the pressure; third, increasing the pumping capacity.

HOBBS BROOK STORAGE BASIN.

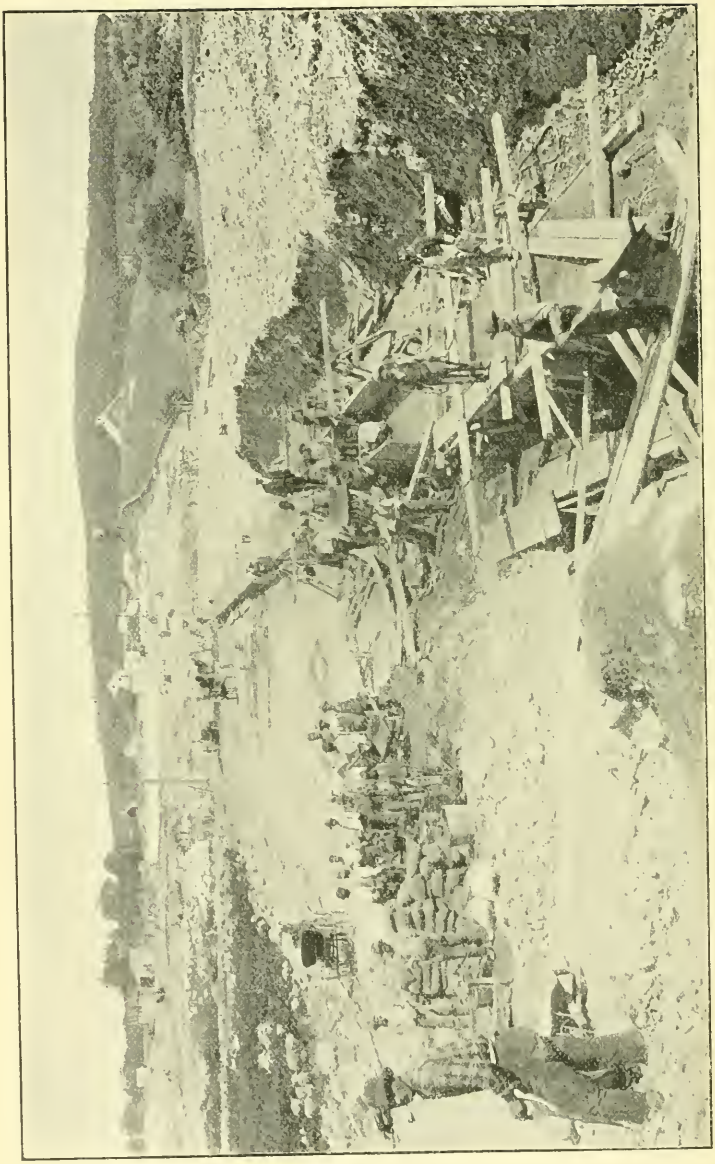
The only way the supply could be increased was by enlarged storage. The area of the watershed of Stony Brook is 22 square miles. This should yield, with adequate storage capacity, about eighteen million gallons daily, instead of the six million gallons now obtainable. To increase the storage capacity on this watershed, about one thousand acres of land have been taken by the Water Board on Hobbs Brook, a branch of Stony Brook, and the work of construction is now well advanced. Two dams are being built: one at a narrow place in the valley, where it is crossed by Lincoln Street, and another, the main dam, at the lower end of the valley near Winter Street, in Waltham. Both dams are built mainly of earth and have concrete core walls; both carry a highway on the top.

The main dam at Winter Street is 35 feet wide on top, with slope of $1\frac{1}{2}$ to 1 foot on the water side, and 2 to 1 on the loam side. The core wall, 7 feet thick, is carried to the bed rock, 16 to 18 feet below the surface; the length of the dam is about one thousand feet.

This dam is pierced by a large overflow conduit or waste way, about 7 feet in diameter, located at the bed of the brook. Flash boards in a chamber built at the end of this conduit regulate the height of the water, and, with a relief waste way or overflow in the crest of the dam at one end, provide an outlet for freshet water. The water in the basin controlled by the dam will be 165 feet above the level of the water in Fresh Pond.

It may be of interest to quote a few prices at which the work of construction at this dam is being done in quite a satisfactory manner. American concrete, of the usual proportions, is being placed, at $3.10 per cubic yard; Portland concrete, $4.75 per cubic yard; plastering of Portland cement, one half inch thick, 27 cents per square yard; excavation and construction of dam, 38 cents per cubic yard; field stone slope paving is being laid at $1.10 per square yard; brick masonry in Portland cement mortar, $10.29 per cubic yard; broken stone furnished and placed, 89 cents per cubic yard.

The dam at Lincoln Street is much the same in design as the one at Winter Street. It has a length of about six hundred feet and a width on top of 27 feet. A few of the prices paid here are as follows: American concrete, $4.00 per cubic yard; plastering, 10 cents per square yard; earth embankment construction, 27 cents per cubic yard; field stone slope paving, $1.00 per cubic yard.



WINTER STREET DAM.

The basin, when filled, will be about six hundred and fifty acres in extent and about two and one half miles in length. It will store about 2,000,000,000 gallons and give about 1,500,000,000 gallons available for use. The entire bed of the basin is to be stripped of soil and muck, necessitating the removal of about 1,900,000, cubic yards of material. Prices for the work have ruled very low, ranging from 16 to 25 cents per cubic yard — the major part being done for about twenty cents per cubic yard. The work is being done almost entirely by the old-fashioned, yet effective, machine — a one horse dump cart.

From the storage basin formed by these dams, the water is to be let down the natural bed of the brook to the lower basin at Stony Brook, and thence by the iron pipe conduit to Fresh Pond. It is proposed to eventually construct another pipe of larger dimensions, parallel with this conduit from the Stony Brook Reservoir to Fresh Pond.

PAYSON PARK RESERVOIR.

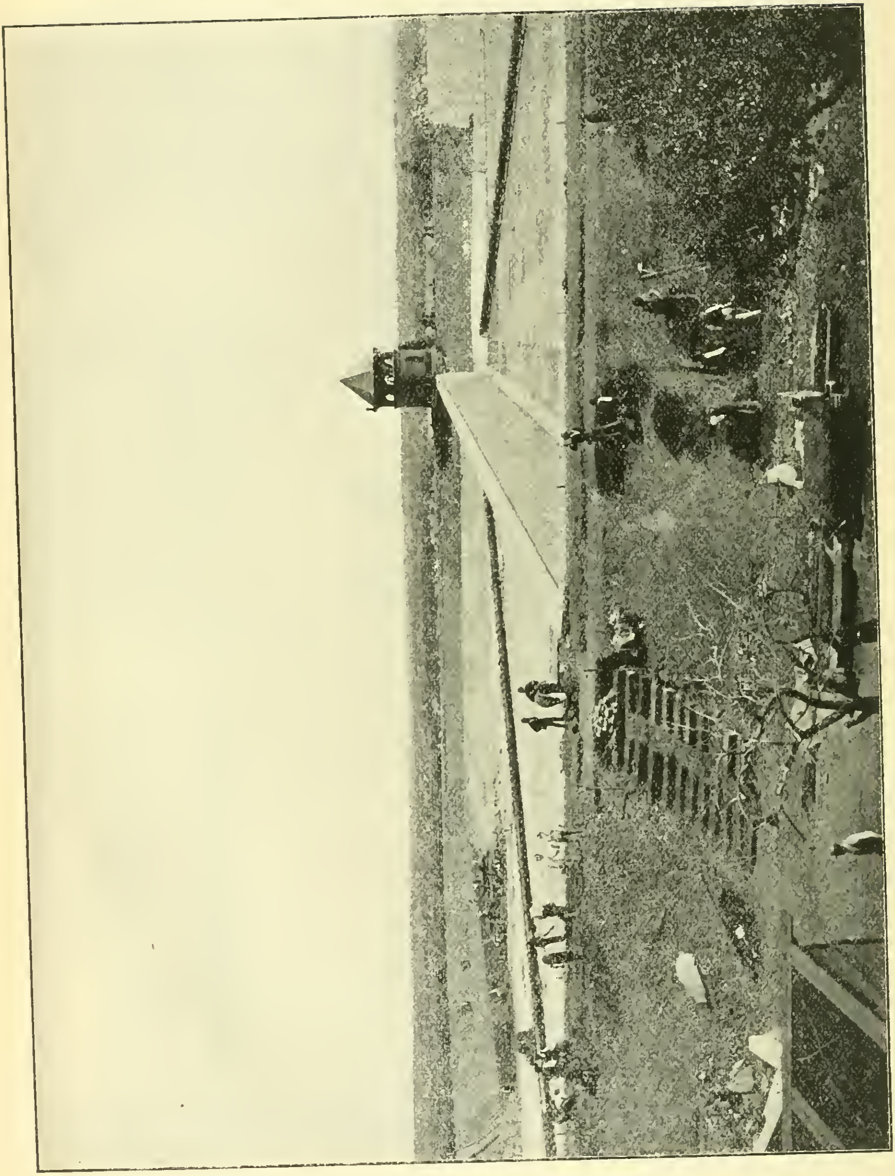
To increase the pressure, a large reservoir is being constructed at Payson Park — this reservoir being connected with the pumping station and the centre of the distributing system by riveted steel pipes, 40 inches in diameter.

This reservoir is 750 feet by 500 feet wide and 20 feet deep, in two compartments, separated by a masonry wall. When full the reservoir will contain 44,000,000 gallons.

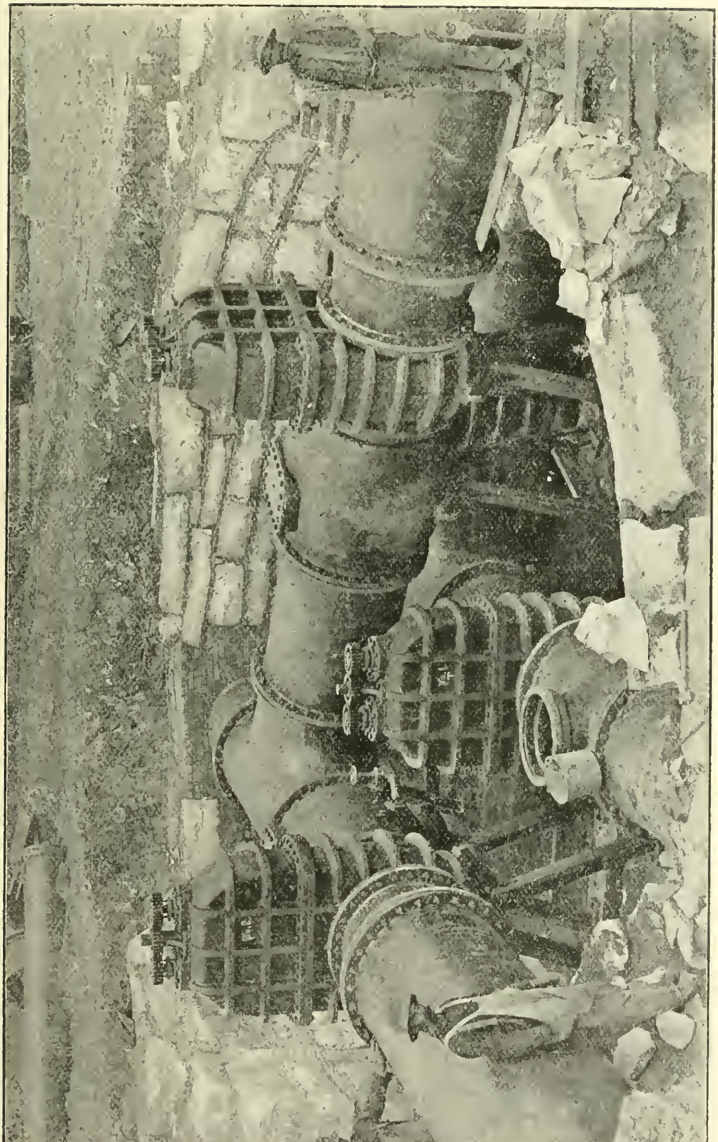
The entire reservoir will be lined with concrete. The embankments made from materials excavated from the basin are of the form shown in the plate.

The core wall is formed of field stone, laid solid in cement, and resting on the sheet of concrete at the natural surface. This is all plastered with Portland cement plaster.

The gate chamber will be circular in shape, and will contain the gates and valves controlling the force and supply mains and waste pipes. The water will be delivered by the force mains at the extreme corners of the basins and will be taken out by the supply main through a perforated drum or strainer at the end of a movable section of pipe, which is jointed at one end to a fixed end of the pipe coming from the chamber, the other end of the movable section, to which the strainer is attached, being raised or lowered by means of a float

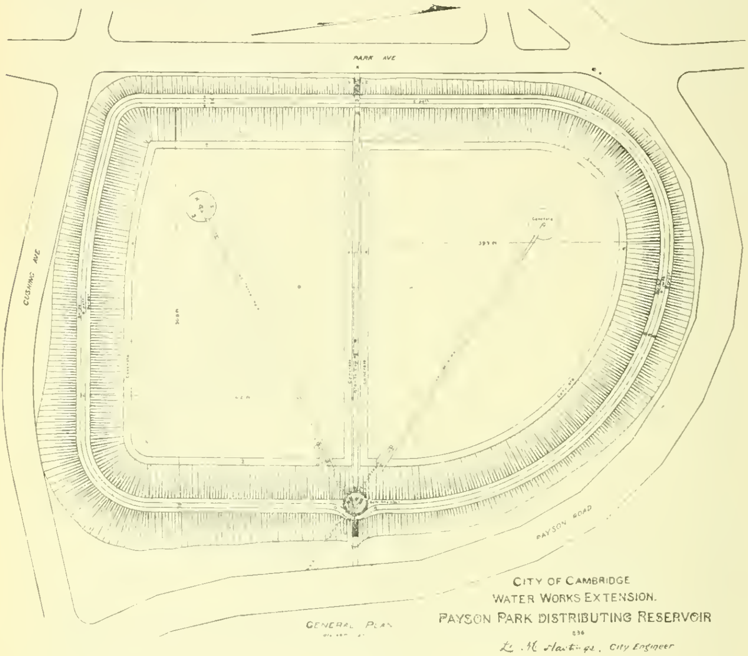


PAYSON PARK RESERVOIR.



GATE CHAMBER AND FITTINGS — PAYSON PARK RESERVOIR.

and tackle. The chamber will be surmounted by a gate house, also circular, of brick and stone, from the second or observation story of which, magnificent views of the country can be obtained. The elevation of the water in the reservoir will be 162 feet above the



water in Fresh Pond, or about the same elevation as the water in the new storage basin in Waltham. The whole city will be supplied from this reservoir when it is completed, giving a uniform pressure and only one service.

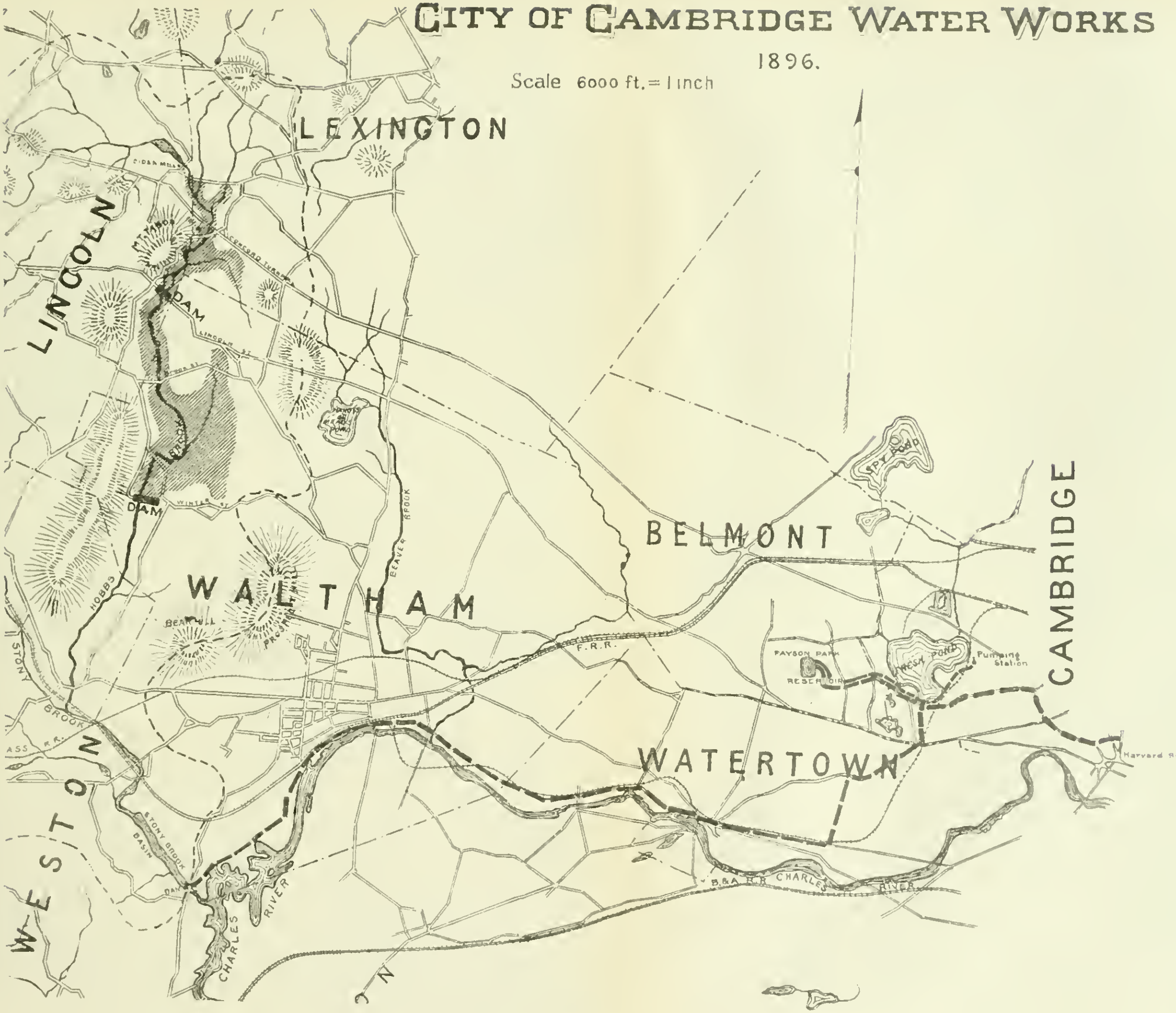
40″ RIVETED STEEL PIPE.

The riveted steel pipe forming the force and supply mains is made of steel plates $\frac{5}{16}$ of an inch in thickness, and about seven feet long, rolled to circular shape and riveted and caulked like an immensely long boiler. Plates were put together in the inside and outside courses, four plates making one section, about twenty-eight feet long. Each section was then dipped in a protective coating made of linseed oil and asphaltum, and baked in an oven till hard. The

CITY OF CAMBRIDGE WATER WORKS

1896.

Scale 6000 ft. = 1 inch

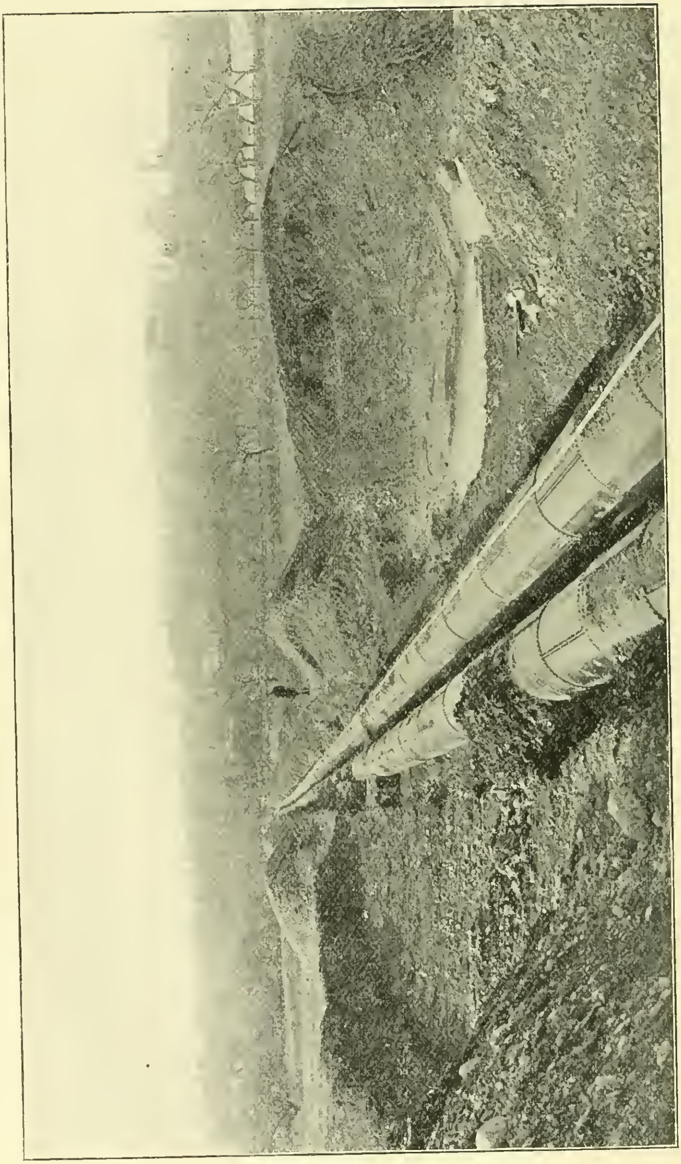


sections were then delivered on the line, and placed in the trench and the sections riveted together by hand. The trenching and refilling for the pipe was done by the city, and the contractor furnished, placed, and riveted the pipe. Twenty-three sections, or 644 feet of pipe, was the largest amount of pipe placed ready for riveting in any one day. Curves were made by shearing the plates to a mitre and then riveting up. One hundred feet was the smallest radius used. At two points on the line the pipe was carried over deep cuts. At one, for a railroad, and once over a roadway. The plates here were $\frac{3}{8}$ inch thick, and the pipe made self supporting between the abutments. In one case a clear span of 75 feet, and in the other a span of 94 feet was used. In the long span the pipe was re-enforced by riveting on to the top and bottom two heavy 6″ angle irons, extending about two thirds of the length of the span. As these pipes were exposed to large variations of temperature, expansion joints were placed at one end of each exposed pipe, to allow a free movement of the pipe. After the pipe was placed in the trench and riveted up, it was tested in sections of convenient length, to a pressure of 100 pounds per square inch by water pressure, and all leaks stopped. The joints made in the field and all defects in coating were covered with two coats of asphalt paint. The contract price for the pipe, complete and tested in the trench, was $4.57 per lineal foot. The cost of trenching and refilling for the pipe was about $1.75 per foot, making a total cost of about $6.32 per foot. The top of the pipes was placed at an average depth of 4 feet below the surface of the ground.

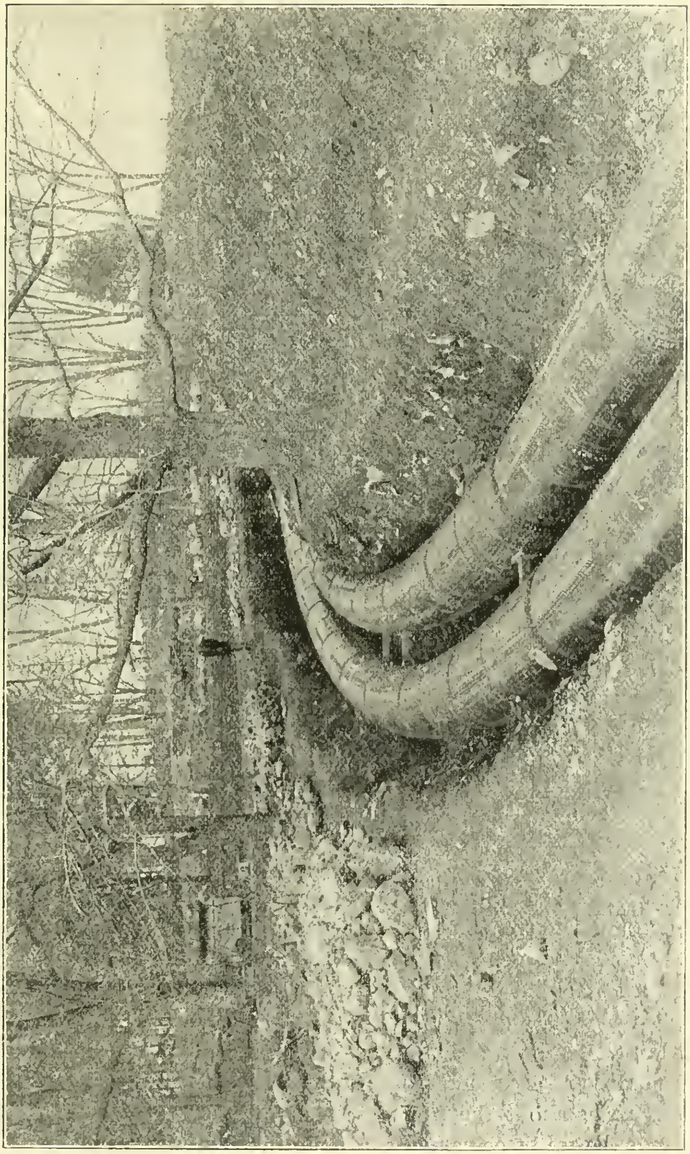
The total length of 40″ pipe laid or to be laid, including fittings and cast-iron pipe, is 24,500 feet. Eighty-four hundred feet of the line was laid with two pipes (the force and supply mains) in one trench, and about eighteen inches apart.

While the pipe was being laid, a curious accident happened, which illustrates the flexibility of even a pipe with as large a diameter as 40″. A stretch of pipe had been riveted up and awaited testing; the trench being in low ground, and not refilled, Oct. 13 and 14, a very heavy rain came and filled the low portion of the trench, and about four hundred and twenty-five feet of the pipe floated up, having less specific gravity empty than water, rising about three feet in places. The trench was dried out and the pipe forced back in place by loading on top, with but little damage to pipe or riveting.

The valves used in the line are 36 inches in diameter, and are made very strong and heavy, by the Coffin Valve Co. It was not thought



40" STEEL PIPE—PAYSON PARK RESERVOIR.



CURVE IN 40" STEEL PIPE — PAYSON PARK RESERVOIR.

that the reduction from 40″ to 36″ in diameter would impair the efficiency of the pipe.

The question of movements of the pipe due to temperature was carefully considered, and a simple form of stuffing-box expansion joint was introduced at the ends of the exposed portion of the pipes, as referred to above, where dangerous strains were liable to occur, and at the connections with the valves.

These joints were made in two sections of cast-iron, one section, having a spigot end, had on the inside a brass bushing attached. The other section had a long, deep hub, into which the first or spigot section fitted. The joint between the two sections was made up of lead and caulked; fifteen of these joints were used on this line. Air valves were placed at the summits and blow-offs at the low points.

NEW PUMP.

The pumping capacity is to be increased by the addition of a new high duty pump, of a capacity of 20,000,000 gallons per day, designed by E. D. Leavitt and now being built by the Groshon High Duty Pumping Engine Company of New York.

This engine will be 53 feet 3 inches in height, with fly wheel 25 feet in diameter, pumping 229 gallons of water for each stroke. There will be about five hundred tons of metal used in its construction. The engine is to possess the high qualities for which Mr. Leavitt's work is noted, with all the modern improvements.

The work above described is expected to cost from $1,250,000 to $1,500,000, and the supply is estimated to be sufficient to last the city of Cambridge for about twenty-five years, or until about 1920.

DISCUSSION.

Mr. Stearns. I would like to ask Mr. Hastings if any part of the system is in use now, either the reservoirs or pipes?

Mr. Hastings. Yes; part of the 40-inch pipe has been in use since last winter, but the reservoir is not completed, nor the storage basin.

Mr. Fuller. I would like to ask Mr. Hastings if all this water is to be pumped. I understood that the distributing reservoir at Payson Park is about the same level as the reservoir at Waltham; can any of the water be carried into the distributing reservoir without being pumped?

Mr. HASTINGS. No, sir. That matter was carefully considered, and it was found to be impracticable to lead it down from the storage basin, which is almost at the same elevation as the Payson Park reservoir. All the water will run down hill and then be pumped up to the reservoir back at practically the height it starts from.

The PRESIDENT. Are there any intervening hills which prevented you from adopting another plan?

Mr. HASTINGS. It was quite a complicated question, and it was also a question whether we should use the Stony Brook basin as a distributing reservoir or build another one. I could not begin to explain all the points, but it was decided after careful consideration that on the whole the best plan would be to use that simply as a storage basin and the other as a distributing reservoir. It seems absurd and unmechanical to let water run down hill and then pump it up again, but that is exactly what we are going to do.

Mr. STEARNS. It is true, is it not, Mr. Hastings, that only a comparatively small part of the water will come from this new reservoir, so even if you provided for bringing that in it wouldn't aid you with regard to the rest?

Mr. HASTINGS. The question was, why should we build the Payson Park reservoir when we were to have another much larger one at the same height.

Mr. STEARNS. I thought the idea was to get it without pumping at all.

Mr. HASTINGS. We couldn't do that. That was one of the questions involved. Part of the year we might draw it direct by gravity from this upper reservoir; the rest of the year we would have to pump against that head.

The PRESIDENT. Will you describe the waste way to that upper reservoir a little more fully? What is the capacity there represented in inches of rainfall, do you remember?

Mr. HASTINGS. I think 6 inches in 24 hours is estimated.

Mr. PRESIDENT. That is carried through those ports?

Mr. HASTINGS. Yes; there are five ports in the chamber, and what I call the relief waste way to serve in case of choking or any possible obstruction is 15 feet wide besides that.

The PRESIDENT. Is that in another part?

Mr. HASTINGS. Yes; in another part entirely independent of this chamber.

The PRESIDENT. That is a waste way?

Mr. Hastings. Yes, sir; for that purpose and nothing else.

The President. Can you tell us a little more fully about the coating of that pipe? Does it peal off, or is it hard?

Mr. Hastings. It seems to be quite hard. There was one place left open through the winter, and this spring, where it was bedded in clay, a few patches of it did come off. The frost seemed to have some effect on it, and some patches came off like a film.

The President. It didn't scale off in great flakes?

Mr. Hastings. No, sir; it was very firm and adhesive, that is in handling and getting it in place.

The President. What do you lay that to, a superior method employed?

Mr. Hastings. It is a kind of japan. It is dipped while the metal is hot, and the pores are supposed to be open, it is dipped in hot asphalt, which is then baked on like a japan. It really is a japan.

The President. Wasn't that same process used in treating some of the other steel lines?

Mr. Hastings. Yes, sir; Rochester and Allegheny.

The President. Didn't it come off of the Rochester pipe in great flakes?

Mr. Hastings. They used two processes. Half of their pipe line was dipped in common asphalt melted in a tank, and the pipe dipped in cold, what is called a maltha bath The other part was dipped in the combination I spoke of, a combination of asphalt and linseed oil, which is baked or fired right on to the metal.

The President. That seems to you to be satisfactory?

Mr. Hastings. It has worked very well so far; of course only time will prove its durability.

The President. How were the seams brought together, and what calculations were made as to the carrying capacity of the pipe?

Mr. Hastings. We didn't have to do a close figuring. The Water Board wanted it big enough, so I figured on an ample basis, and no fine estimates were made of the obstruction that these rings or rivet heads would cause. As long as I got it big enough, and a little more it was satisfactory.

The President. Were the embankments rolled in thin layers?

Mr. Hastings. Yes, sir; 4-inch layers and 6-inch on the outside.

Mr. Smith. You spoke of some portions where you had laid two lines of pipe. Was the pipe of different diameter, or why were the pipes laid in that way?

Mr. HASTINGS. The idea was that in running from the Fresh Pond station to the reservoir and then back into the city the two lines came together part of the way and then they diverged, one going to the pumping station and one to the city.

Mr. SMITH. It was all the same size pipe?

Mr. HASTINGS. Yes, exactly the same.

Mr. SMITH. But the water flowing in different directions?

Mr. HASTINGS. Yes, sir.

Mr. STEARNS. Is there a connection between those pipes so one can be used independently of the other?

Mr. HASTINGS. Yes; there are three gates and cross-over connections so that one can be used and switched off and the other one used alternately.

Mr. STEARNS. So by having the two pipes you have a reserve, and ordinarily you intend to pump to the reservoir through one and draw through the other, or will you have them both open?

Mr. HASTINGS. They would both be open and we can pump through one and draw through the other, or they can be switched off so we can use either one as a force main or as a supply main.

Mr. STEARNS. I don't know as I quite understand. Is it the intention to open both pipes so the water will go freely, or is all the water to be forced up to the reservoir through one pipe and to come back through the other pipe?

Mr. HASTINGS. Well, ordinarily we would pump right into the reservoir and draw it right back again.

Mr. STEARNS. Is that with the view of improving the quality of the water?

Mr. HASTINGS. Yes; the idea is to keep a constant circulation of water in the reservoir. If we didn't do that we should have stagnant water in the reservoir. We could pump into the circulation and simply have that pressure to pump against, but that would make stagnant water there, so it was thought best to pump into the reservoir and then draw it out.

Mr. STEARNS. So it is for the purpose of maintaining the good quality of the water?

Mr. HASTINGS. Yes, sir; that is the idea.

Mr. FULLER. Couldn't you have an arrangement of check-valves so you could discharge the water at the further end and take it from the nearer corner of the reservoir?

Mr. HASTINGS. Not if we only use one pipe for the force and

supply main. If we pumped 6,000,000 gallons a day we would have the reservoir full and the water would simply go right around, and not into the reservoir at all, and the water in the reservoir would stay there as a pressure. That was one reason why we had two lines. The water will have now to go to the reservoir and come out, while if we had only one line and used that as a force and supply main, the water would stay in the reservoir and become stagnant.

Mr. Fuller. Couldn't you have a check-valve so the water would be discharged at that end and only come back at this end?

Mr. Hastings. But ordinarily you would be only pumping your consumption, which would mean you would pump into the city direct, and there would be no water going into the reservoir at all. It might lie there three months and never change. By having the two lines there has got to be a circulation.

Mr. Fuller. You mean the water which was pumped would be used, and the water in the reservoir would remain there?

Mr. Hastings. That is just it.

Mr. Smith. Can you give us any explanation of how you were able to get such low prices on your work?

Mr. Hastings. No; I don't know as I can. We had quite a large number of bidders, and we seemed to strike a low period in the market. The contractors are doing very satisfactory work for the most part.

HOW TO SECURE PURE WATER FROM A SURFACE WATER SUPPLY.

BY JOHN C. HASKELL, SUPT., LYNN, MASS.

[*Read June* 10, 1896.]

In considering a subject that has been such an essential factor in the very existence of mankind since their creation, it would seem that little would remain to be said, and that all of the steps to be taken in the practical development of a system of surface water supply for our cities and towns had been in the past so fully developed and thoroughly tested by their subsequent use that we would have no differences in opinion. As to the methods to be followed to maintain at all times in our distributing reservoirs water of a good, wholesome character, with no disagreeable taste or odor, destitute of color and not dangerous to health, all will agree that water to be used to quench our thirst should possess these qualities.

I will, at this time, state that we have in the basement of the City Hall a laboratory in which biological examinations are made weekly, of samples of water taken at points one foot below the surface and one foot above the bed of all our ponds. During the meeting of this Association drawings showing all of the different organisms that have at any time been discovered in our water supply, also an opportunity to examine such organisms as are at present to be found in any of our ponds, together with an explanation of the details necessary to a thorough study of the character of the water, will be open to the members of the New England Water Works Association. All interested are invited to visit the laboratory on any day between the hours of 8 A. M. and 5 P. M.

Although this is a subject of great importance, and one which covers a wide field for special study in different directions, upon each of which much information is occasionally presented by specialists who are giving their undivided attention in one direction, it is one which has not been given the prominence it deserves, and as yet is imperfectly understood. In order to bring this subject before you,

I will endeavor to present some of the details brought to my observation since the inception of our system of water works, together with the effects that I consider them likely to produce upon a surface water supply.

It is known to all engaged in the management of surface water supplies that the quality of water furnished by them for daily consumption is not always of the best character, and that it is liable to differ in quality from time to time.

Such changes should be avoided, if possible, and the standard of purity maintained at all times up to the best permissible in that system of water supply. To accomplish such a result it is necessary to know what produces the various changes so noticeable, and of the best methods to be followed for their prevention.

One of the principal reasons why our knowledge in this direction is so insufficient is the additional expense to be incurred in the construction and maintenance of a system, with special attention given to securing its purity.

The usual course pursued by expert engineers until within a few years, in providing a system of water supply by artificially storing water in a reservoir formed by constructing a dam across the valley of a small stream or river, gave very little thought as to the liability of a change in the character of the water impounded therein.

Water was what was wanted, and the solution reached forward to was quantity, not quality.

From the first use of water from these artificial reservoirs it was found that at times it possessed very disagreeable qualities.

While the causes in the frequent changes in the character of water impounded in reservoirs was not at first understood, the careful and constant examinations of their waters, both chemically and microscopically, has furnished us with sufficient information to show us what produces these changes, and from what particular organisms or different combination of organisms we are deriving these undesired qualities in our water.

Some of the organisms existing in large numbers at times in our waters are not injurious in any way to the character of the water except to sight. Others, although invisible to sight, are disagreeable, both in taste and odor; some possess all of the disagreeable attributes. While it is generally claimed that the presence of large amounts of decaying vegetable organisms in our waters is not dangerous to

health, it is certainly very disagreeable, and in my opinion not altogether harmless.

There is now no mystery as to what produces the poor water in our reservoirs. The cause in any case can be ascertained. The proper solution of the best and most practical methods of eliminating all injurious organisms from our waters is the feature to be desired. As far as possible all dangerous contributing constituents should be excluded. Rain falling upon a water-shed is comparatively pure.

To gather this water falling upon a water-shed, impound it in a reservoir and deliver it at the tap in the city in a pure condition at the least expense, is a problem that is far from being solved. From the first contact of the rain with the earth on the water-shed its liability to contamination begins.

Upon a hilly wooded country containing no artificial pollution, comparatively no danger exists. An examination of the water found in the brooks at the base of such areas shows water of the best character. Upon reaching low, swampy areas, where the flow of water is impeded from the level nature of the ground, giving it time to settle into the soil and stand among the roots of shrubs and trees until it has absorbed some of their taste and odor, is one of the first sources of contamination.

This danger should be eliminated as far as possible by separating the swampy portion of the water-shed from the hilly, by ditches at the edge of the swamps sufficient in size to carry the water from the upland around the swamps. Where the depth of soil will admit, the water-table of the swamp should be lowered by means of ditches to the gravel or sand below the soil, thus requiring the water to simply pass downward a few feet through the soil to the gravel below, instead of a long distance through the surface of the swamp.

A partial result in this direction is shown as resulting from work upon the water-shed of Walden Pond in 1895, which reduced the color of the water in the pond, as shown by the weekly examinations, from 76 in 1895 to 43 for the corresponding time in 1896. This reduction in color is perceptible and can be expressed in figures; undoubtedly the diminution in taste and odor, which cannot be shown so clearly, was greater.

After providing the best channels to convey the water from the entire water-shed, we come to the artificial reservoir. Until quite recently expert engineers made no attempt to remove the soil and

perishable material from the bed of new reservoirs, claiming that the expense should not be incurred, as the beds of the reservoirs when covered with water would improve from year to year. Until within a short period, less than ten years, they would become equally as good as the old ponds which were formed by nature. This reasoning, however, has been in many cases proven to be erroneous, as no perceptible improvement has been found to take place in some of these reservoirs in a longer period, and in all probability these ponds will never furnish a good bed from natural causes.

It is also known that natural ponds are not entirely exempt from these periodical changes in the character of the water, some being much less liable than others, but no absolute certainty exists that their water will be pure at all times.

Our experience is based upon artificial reservoirs.

The two first, Breeds and Birch ponds, were purified to a large extent by natural causes, but still each year at times furnish growths of organisms that render the water disagreeable. The improvement in the other ponds, Walden and Glen Lewis, has not been so rapid. In Glen Lewis no perceptible improvement has been seen. Its value as a storage reservoir, however, is not destroyed, from the fact that the water is of good character a sufficient portion of the time to allow its use without any waste.

In Walden Pond some work has been done to improve the character of the water. This work became necessary from the fact that the total capacity of Breeds and Birch ponds, from which we have been obliged to draw water during the summer months, would be insufficient to supply the probable consumption for the summer of 1895; and it was necessary to delay, if possible, the growths of organisms in Walden Pond sufficiently late into the summer to meet the expected deficiency with an ample supply of good, potable water.

In our endeavor to accomplish this result, and with a view to ascertain as nearly as possible whether the results to be obtained by removing all soil from the bed of the pond might not be equally well subserved by a covering of sand or gravel over the soil to a sufficient depth to effectually destroy its pernicious effect on the water, a portion of this area, containing mud from fifteen to thirty-five feet in depth, was selected as an area upon which the expense of removal would be practically prohibitive, and also where the chances of failure to secure good results were most likely to be found.

The surface of this area was mud, with water standing near and upon a portion of its area, it being of such a nature that gravel would readily sink to an unknown depth. All stumps within this area were allowed to remain. Other stumps were removed from the adjacent area, from which all soil was to be removed and placed over the muddy area to form a more stable bed than the wet soil, finally covering all with about one foot of gravel. The bed of the pond was burned over and was exposed to the alternate freezing and thawing through the winter. The success attendant upon this effort is shown from the fact that the water became unfit for use on May 25, 1893, and on May 23, 1894; but in 1895 the water remained a good, potable water, remarkably free from algæ growth until July 10, a sufficiently late date to furnish the needed supply, when it was again wasted to permit further work in this direction. An examination of the different exposed areas showed an equally good appearance of the covered areas and those from which all soil was removed.

Immediately after the bed of the pond was exposed to view, samples of the gravel from the areas cleared, and soil from the areas not disturbed, were taken, to determine as far as possible what advantage was gained by our labor.

These samples, in equal numbers from the sand and soil, were collected at points not more than two feet distant from each other and placed in a dish of water to develop all animal and vegetable life that could be germinated. In the specimens taken from soil, most of the species of organisms previously found in the waters of the pond were well enough preserved to commence an active growth. The samples of gravel contained practically nothing, although gathered in such close proximity to the others. While there is no question but that the removal of all soil and perishable matter from the bed of the reservoir is a step in the direction of securing the purest water, work of this character has not been completed for a sufficient time to fully prove its efficiency. I will, however, present some or the features incident to its practical development that occur to me.

The objections to organic matter in the pond are, first, that it supplies the food necessary to sustain the growth of plant life beneath the water as abundantly as it provided for the growth of grass or trees before its submersion.

Secondly, it also provides a resting place, and protection for the

existence of the seeds and spores of plant and animal life, as is so plainly seen from the comparisons of the samples of gravel and soil taken from the bed of Walden Pond in 1894. It will also prove a potent factor in increasing the color, taste, and smell.

The counteracting agencies that are to be feared are that the same causes that furnished the deposits of soil removed will still continue their work. The washing of the hillsides into the valleys will always continue, and from year to year the inflowing waters will carry organic matter that will be deposited by sedimentation upon the bed of the reservoir, possibly in sufficient quantities to supply in a short period of time all of the food necessary to support the vegetable and animal organisms, and thus neutralize to some extent the good results produced by the process of cleaning the bed of the pond. Again it may be found that the water flowing in the bed of the streams, at times contains sufficient food to sustain the objectionable organisms. That this may be probable is shown from our experience in our distributing reservoir in April, 1894.

This reservoir, although small in area, its water surface being about five acres, with a capacity of 21,000,000 gallons, in all other respects was of a good character to preserve the purity of the water, the sides being in the nature of an embankment sloping at the rate of two feet horizontal to one foot vertical, with paved slopes and a puddled bottom, the depth of the water, from day to day, from thirteen to fifteen feet. Water was taken from Hawkes Brook and pumped direct into the reservoir. Notwithstanding these favorable conditions, we had in April, 1894, a growth of organisms in the reservoir in sufficient numbers to prove somewhat disagreeable.

Without doubt the food necessary to sustain their growth was brought with the water. We shall in the immediate future have an opportunity to test the new feature, as the entire bed of Hawkes Brook Pond, now in the process of construction, will be thoroughly cleaned.

The next step is to still farther improve the quality of the water by filtration. Although the necessity of filtering water supplies becomes more important according to the density of the population, and in Europe and in tropical countries great numbers of people died from the fearful effects of pestilence engendered and distributed through the medium of their water supplies, the true cause of these diseases was not understood and it remained to scientists of quite

recent date to explain the dreaded mystery which has been the cause of such terrible loss of human life.

The first attempts to improve water by filtration are very ancient and crude in operation, and it is not until a quite recent date that intelligent study has been given in this direction. The comprehensive and careful studies instituted by the State Board of Health and prosecuted in their laboratory at Lawrence, without doubt present the most valuable information to be found upon this study. A careful examination of the tables giving the results secured by their different arrangement of filter beds, presents information of the greatest importance. A large number of experimental filters, embodying various forms of construction, have been in continuous operation under conditions easily conformed to in the practical operation of a system of water supply, a sufficient length of time to have furnished the desired data to show which are the best forms of construction to be used, and also the proper detailed work necessary for their maintenance in proper condition to perform effective work at all times.

It has been found by their examinations that several forms of construction will remove ninety-nine and a fraction of one per cent of all of the bacteria present in the water, a result that is greatly to be desired in our search for the purest water. There are also various mechanical filters capable of doing very effective work.

The location of a system of general filtration should be at the nearest point practicable to the point of distribution.

Additional filtration can be secured at the faucet; many forms of filters have been used, from a cloth tied over the faucet, which acted as a strainer, to the very best mechanical filter yet designed.

Each individual has, through this agency, an opportunity, if so desired, to secure water of the best character.

I know of parties who filter and boil water used for drinking purposes, keeping a supply of water so treated in store in their refrigerators.

Water so treated should be perfectly wholesome in character.

The most thorough methods of filtration have not succeeded as yet in removing all of the odor present in surface waters.

This feature can be largely eliminated by aeration.

This method of improving the quality of our water has not as yet received much attention, but does not present a very difficult problem for solution.

Undoubtedly the time is not far distant when no surface water supply will be considered satisfactory that is not properly filtered.

The importance of filtration has already been recognized in the German Empire by a law obliging its use in all surface water supplies.

DISCUSSION.

Mr. Cleaver. We have all been deeply interested in listening to this paper, which so clearly presents the experimental and philosophical sides of this question. We are all of us more or less familiar with the various methods of filtration thus far developed, but there is one point in this paper that especially attracted my attention, and I would like to ask Mr. Haskell what he refers to when he speaks of the natural forces which go to the purification and the rendering potable of a surface water, and whether those natural forces are sufficient to solve the problem.

Mr. Haskell. That question, Mr. President, opens up a sufficiently broad field for treatment in an entire paper. Of course the natural causes referred to are the elements. The sun has an important relation to natural causes. The water which is stored in the pond is a most potent natural cause. Frost is a very important factor in the action upon the surface of the bed of a reservoir; and heat also performs an important function. To illustrate the effect of natural causes upon a pond after it is put in use, we will consider a pond recently constructed, into which the water is allowed to flow until it covers the entire bed of the pond at the height of the overflow. Most ponds have a steep rise at the outer edges to the sides, which are sometimes wooded and sometimes ordinary tillage land. It is on these slopes that the good effect of the action that the water produces upon the soil is first to be found; and to a certain extent on all the hilly portions of the bed of the pond it does the same thing we do where we undertake to clean the pond out by excavating the soil. The first thing noticed is the washing of the water on the soil, when the wind blows it, which loosens the soil at the extreme point where the water touches it, and the soil gradually descends down towards the bed of the pond below. As ponds usually are handled, the water in the pond is gradually drawn lower and lower until perhaps the water level is reduced below the precipitous part of the bed of the pond. A certain amount of soil is washed down in

the first year. In the winter the frost disintegrates and loosens areas that might not have been permeable before the water gets in, and the frost swells and breaks up the particles of the soil, and under the influence of the wind the water washes them down, so that in the course of a short series of years you get as perfect work around all of the outside slopes of the pond as can be performed artificially. The only difference is that the mud is washed down into the deeper part of the pond instead of having been carried away entirely outside the limits of the pond, as it would have been if the work had been done artificially.

Now, the amount of work performed by nature largely depends upon the contour of the reservoir. In a very shallow pond, of course, it only extends to a point slightly below the surface of the water when the pond is full. If the pond were of sufficient depth, and these processes were continued long enough, I have no doubt that the soil would ultimately be removed to a point sufficiently low beneath the surface of the water so there would be no opportunity for the organisms to develop in the soil. There is a point, — I wish I could tell you how deep it is, — that if the water was kept above, there would be no danger to be apprehended from mud in the pond; but I do not know that that point has ever been determined yet. These natural causes work in all reservoirs, and in some they have proved sufficient to bring the bed of the pond into very good condition; but in some, particularly where the water is not deep, they have not proved to be of very much value.

Mr. Holden. I notice Mr. Haskell said he drew the water off to let the frost work on the pond during the winter, and didn't fill it until spring. Is that any better than it would have been to have filled it in the fall, if that could have been done, and then to have drawn it off in the spring and allowed it to refill?

Mr. Haskell. In our case we let the water out, because we had poor water, and the pond would refill with water of better quality. And there was another reason for letting it off. There were large numbers of organisms in the water, and also their seeds and spores that will multiply in great numbers; and we expected that during the winter the frost would kill, to a great extent, these seeds and spores. Then again, we know that these are near the surface, some of them are on the top, and so we burned it over, hoping by means of fire to destroy all we could. Then the shorter the length

of time the water remained in the reservoir, the less opportunity would be given for the germination of these seeds and their growth. We let the water off through the winter and did n't undertake to store it until the spring rains started an abundant flow of water. The melting snows and the natural rainfall was sufficiently great so we were not obliged to commence to store our water until the latter part of the winter, nearly in the spring, in order to gather all the water we desired. We didn't entirely fill the pond but we got an abundance of water, and the good quality of that we did get was more important to us than it would have been to have a large amount of poor water.

Mr. Noyes. I would like to ask Mr. Haskell if, by that method of drawing the water off and allowing the bed to freeze and the frost to act upon it, the quality of the water obtained from that reservoir has been permanently improved.

Mr. Haskell. A sufficiently long time has not yet elapsed to enable me to answer that question definitely. It undoubtedly helped us through the trouble that we were in at the time. But I should be doubtful whether in a bed constituted as ours is it would be of much permanent value, because the greater portion of the bed is level. I doubt if it would ever permanently improve from natural causes. I am satisfied that with the conditions to be met with in that pond, there never would be a proper bed made through the action of natural causes, but it will have to be cleaned thoroughly.

The President. Did I understand you to say that the action of the water on the sides of the pond, where the shallow places were not stripped off or protected, would in time improve the sides of the pond?

Mr. Haskell. On the sides of our pond there were points where it was 2 feet, and some points where there were not over 6 inches of soil, and to have renovated that thoroughly artificially would have required at some points an excavation 8 inches in depth, and at other points 2 feet or 2½ feet in depth. Supposing, for instance, the full pond is 17 feet, as the water lowers down to 16 feet a sufficiently heavy wind to make a sea a foot high would have a washing action on the precipitous bank, and each time the water runs up a foot on the bank any portion of the soil which has disintegrated enough to wash down will be brought down; and then as the water goes down from the 16-foot level to 15 feet the same process will be repeated, and so on. And each year, in the winter, certain portions of this soil, that perhaps are too hard, or of too

solid a nature for the water to bring down, will be broken up and disintegrated by the frost. Supposing there came a rain and the soil filled with water, and then it froze right off that night, it would break up that soil so that the water washing on it the next day would bring it down, when perhaps the year before it was not able to do so. And in a certain period constant work of this kind would remove the whole of the soil.

The PRESIDENT. How many years would that take?

Mr. HASKELL. In Birch Pond there is a pretty good opportunity to see. In seven or eight years the upper part of it, was entirely washed out; I think, in fact, in six years. The reason I cannot tell you exactly about it is this, that I was not taking notice of it, and after the pond had been constructed for a certain length of time we raised it, so of course that made a new starting point. The pond has not been in existence for more than thirteen years, and the whole of the soil on the steep slopes has been washed down; it is all good gravel now, just as good as if we had artificially dug it out and teamed it away all around the edge of the pond. I could not say how many years it has been so, but I should say for five or six years certainly there has been practically no soil whatever on the upper portion of it.

Mr. NOYES. The question asked by Mr. Cleaver and answered by Mr. Haskell opens up a very interesting question in regard to the possibility of improving the quality of water which may be stored in ponds or artificial reservoirs by the drawing off of the water from the reservoir and exposing the bottom and sides to the action of the frost in winter. I believe some years ago a similar trouble to that which Mr. Haskell speaks of occurred in another large reservoir in this State, and that that experiment was tried, and the engineer who advised it was sanguine it would improve the quality of the water very materially. We have with us to-day Mr. Goodnough, one of our members, and chief engineer of the State Board of Health. If I remember rightly he has been studying, and has had some recent opportunities of observing the effect of this method of treatment; and I would, with your permission, Mr. President, ask him to state to the Association what the result of those observations were.

Mr. GOODNOUGH. The reservoir to which Mr. Noyes refers was drawn off, I think, in the spring of 1892, and it was filled again in 1893. During 1894 the water was excellent, and during 1895 up to

the latter part of the year, about September. Since then I believe it has been worse than ever. I understood Mr. Haskell to say that experience had not been had for a very long time as to the results of cleaning reservoirs. I may say that there are some reservoirs in the State which have been cleaned for some ten years, and experience with those has been very satisfactory.

Mr. Haskell. I should like to know if you refer to Basin No. 4 in Boston?

Mr. Goodnough. I do; yes.

Mr. Haskell. That seems to me the most notable reservoir of that kind of construction, and of course there is no question but what it did excellent work. There are always in all reservoirs contributing elements which render the success in the case of some better than in others. I have carefully examined all of the analyses that have been given by the State Board of Health of the waters in Basin No. 4 since that work was done, also in Basin No. 3 and Basin No. 2. The analyses would go to show that the results derived are the best in Basin No. 4.

It is well known to any one who is studying the growth of organisms that where analyses are taken but once a month, you know very little about what may occur in the pond. Organisms may arise, come to maturity and disappear between the times of examination, — perhaps not absolutely, but to a great extent. And consequently I cannot talk on what may have been found in basins 4, 3 or 2, with the knowledge that I would like to have. President FitzGerald has made an exhaustive study of those reservoirs; he has made examinations with sufficient frequency to thoroughly understand the matter. I refrained from referring to those ponds in my paper from the fact that I did n't know enough about them to speak with confidence. But I have discovered in the analyses of the State Board of Health sufficient cause to lead me to think that at times even the water of Basin No. 4 was quite disagreeable.

Mr. Holden. I would like to inquire whether, in clearing those reservoirs, all vegetation and stumps were either removed or covered up, or was some left exposed?

Mr. Haskell. I suppose Mr. Holden refers to these reservoirs 2, 3 and 4. I understand that in Reservoir No. 4 the most thorough work possible was done. I think it was done more thoroughly than ordinarily would be attempted, and if ever there was a reservoir

where such work would be effective, it is that one. The whole condition was perfectly understood, and everything was done in that connection to make the waters of Basin No. 4 perfect. In basins 2 and 3 the loam was excavated within 8 feet of the high water line. As I gather from the reports, Basin No. 3 contains the poorest water at present. Basin No. 2 would come second, and Basin No. 4 the purest; but none of them, I think, contains water of such character as it is possible to secure by means of filtration. Of course all of you understand that if you take ninety-nine and a fractional per cent of all the impurities out of the water, even in Basin No. 4, the water must be better than it was before. The only question as to the necessity of filtering it is when the public get educated up to the point where they don't like water without its being filtered. There was a time when people were killed by drinking water, and they didn't complain about it because they didn't know it hurt them. They used to say about our Lynn water, that the people didn't know enough to complain about it, but after a time the people demanded better water, and the time may come when they will demand it shall be aerated, which would undoubtedly make it a little more pleasant to use.

Mr. Hawes. I would like to ask Mr. Haskell if, in studying this method of improving the quality of the water by covering the bottom of the reservoir with a layer of sand, any conclusions were reached as to the length of time the improvement will continue; that is, whether or not the effect will be permanent, or whether the idea was to provide a bottom for the reservoir which could be cleaned.

Mr. Haskell. It is the evil effects of what may come from the organic matter which we want to protect ourselves from. Now, these evil effects are incident to the organic matter, and they can be avoided by removing the organic matter. You take a seed and plant it in the ground, expecting to get something from it, and if you plant it a certain depth below the surface it germinates, and you get the desired result. Now, here is a seed you do not want to have germinate. It is already in the soil. The only thing to be determined is the amount of covering necessary to entirely prohibit the germination of the seed. While I say a foot, I really think that six inches would be equally effective, provided that the six inches remained perfectly undisturbed, because there are very few seeds

that would come up through six inches of gravel in the short length of one season.

The PRESIDENT. Such frequent reference has been made here this afternoon to some of our basins on the Sudbury River, that perhaps it may be pardonable for me to say a word on the subject, for I have taken a great deal of interest in it for a number of years. In 1880 we first began, on the Boston Water Works, the stripping of our basins, and the treatment of shallow flowage, as we call it. I think that was the first comprehensive treatment that any storage basins had ever received, of that kind, certainly so far as I can find out; and it arose in this way. The basins had been built without any clearing to speak of at all; the trees were simply cut off, and the stumps and the swampy areas and loam and everything remained very nearly as they were originally in the basins. In the course of three or four years we began to have a great deal of trouble with our water, and it grew worse and worse. The albuminoid ammonia, which is a very fair measure of the organic matter in the water, ran up to 0.0500; it is now down to 0.0160 in 100,000, I think, as about the average. When the water absorbed all this organic matter from the soil and the roots, the amount of growth in these basins began to get very large, and that gave food for animal forms. For instance, the sponge came in very great quantities. I have seen the sponge in our Sudbury aqueduct at Farm Pond for the first two miles, from the gate house, so thick on the bottom (which had all been thoroughly cleaned six months before) that you could walk the whole distance without treading on the brick work, — great patches of sponge a foot and a half in diameter and an inch in depth; and that growth had come in six months. I could bring up a great many instances of a similar nature.

This led me, for a great many years, to devote a good deal of attention to the matter, and I have collected a mass of information which I hope to put in shape sometime for the profession. We cleaned out a large part of Basin 2 in 1880, and previous to 1883, Basin 3. Neither of those basins was thoroughly cleaned out, but they were very much improved. Down to a certain point everything was taken out, and a certain treatment was made of the sides so that there was not less than eight feet of water around them.

When Basin 4 was built the whole of the bottom was stripped, but

it was not given as thorough treatment as Basin 6 received afterwards. Basin 6 was completed about two years ago. We have a long series of very careful chemical analyses and bacteriological and biological examinations of both basins 4 and 6, covering a long period, and also of some of these other basins. The proof is conclusive to my mind that you cannot expect anything like the same improvement in water stored in an uncleaned basin that you can in one which is thoroughly treated in that way. I think very probably our treatment of Basin 6 was more thorough than necessary. That is, it hardly paid us to expend so much money in taking out the whole of the subsoil. We took out of Basin 6 not only all the material on the surface, but we took the subsoil down to two and three feet in depth. In fact, the whole of that basin is perfectly clean down to the gravel or the clay or the sand, and it is marvellous the work that basin does in the way of improving the stored water.

Mr. Haskell referred to the natural agencies at work. Now it is necessary for us to keep clearly distinct in our minds the natural agencies for improvement, and the natural agencies working in the other direction towards the deterioration of the water; and it seemed to me that perhaps for a moment Mr. Haskell got off the track there, although I may be mistaken about that. But I will give a little *résumé* of that as it appears to me. If you have the water beating on the sides of the banks which have not been treated, that action goes on for years and years. I have seen it going on after the passage of thirty years. That is to say, the banks were still caving under the influence of storms and waves, and the organic matter in the soil was going down into the water at the end of thirty years. And I have also seen after a lapse of forty years, by special examinations of areas which were shallow and which have not been treated, pretty good proof that the action of the organic matter is still going on; while in the same pond over another area where there is not this shallow flowing, it is not going on.

Now I have noticed on the sides of ponds, that while a certain amount of gravel may form, yet if you dig down into it you will find that there is loam under it, and it is only waiting for a big enough storm to be exposed and washed down. So I believe if a man builds a reservoir and waits for that kind of action to improve it, he will wait until he is a pretty old man, and that the only way to get it is by such treatment as we are carrying out on the Boston Water Works.

Now, a single word, because I think it may be useful to you and save you a good many thousand dollars if you have work under way, or if you are proposing to dig out shallow portions of your ponds, and that is, to fill those portions, instead of excavating them, with the material which comes out from further down. In that way you will kill two birds with one stone, because you will save digging out a good deal of material over the whole area. And then, if you cover the slopes with gravel, in six or eight years you will have very clean shores, and the improvement in the water will be very great.

Now there are places where you cannot treat the water in this way, — small areas, small water-sheds, where it is impossible to get large storage basins, and where you cannot provide for this wonderful system of oxidation which goes on in Nature; and there it seems to me that nothing but a filtration system will make the water safe. I have a number of small places in mind where they depend on perhaps two or three square miles of drainage area, and the water from it, not being impounded in large reservoirs where it can have an opportunity to improve, must necessarily go right down the throats of the people with whatever it contains. And anyone who has had much experience knows that there is hardly anything more unsafe to do in the world than to drink water out of an ordinary brook, even if it is in comparatively good neighborhood. The things he is liable to get down his throat would surprise him after a study through the microscope. These things, it seems to me, it is extremely important to exclude from a water used for domestic supply.

I wish to add that in comparing Basin 4, which Mr. Haskell has so highly recommended, with Basin 6, which was still better treated, interesting results are noticed. The two basins are about the same size and have about the same drainage area. One was well stripped and the other was most thoroughly stripped, and the difference in the work that those basins do is in favor of the one which was most thoroughly stripped. Whether it is enough better to pay for itself is a question to which I am going to give a little more consideration.

We have to-day going on in one of our large natural lakes something which illustrates what Mr. Haskell has spoken about; that is the sudden growths which may come up and disappear in almost a day. Uroglena are among these growths, and we have that to-day in one of our large lakes. It is simply a question of giving the water enough organic matter to produce that life, and the life is sure

to come. I knew it was coming in this case, and it was a wonder to me it didn't come before, because owing to the large amount of organic matter which was thrown into the lake recently, by causes beyond our control, by the filling of the railroad across one end of it, the organic matter was sufficient to produce an abnormal growth. Uroglena will come up and disappear in a short time. It does not appear without a cause. Water will absorb matter like a sponge, and it is only necessary to give it the organic matter in some form, and it will take it up and then you will have the result following.

I do not myself take much stock in drawing off a pond and allowing it to freeze, or anything of that kind. It does not seem to me a comprehensive treatment. It may have a certain effect, but I think in another way from what Mr. Haskell suggests. I have noticed in the case of Basin 6 and of Basin 4, which are very deep, about fifty feet, that the water at the bottom at the end of this long stagnation period in the summer has the full amount of oxygen in it; it has not been deprived of its oxygen. But you put that same water into a deep pond which has not been treated, and the oxygen will be used up and the water become offensive. But that is a subject on which more can be said by and by.

Mr. Haskell. I would like to say, Mr. President, that perhaps you and I are on the same footing when we come to consider the question of the purity of water. The remarks I made, to which you refer, were not expressing opinions I had as to the best way of securing the purity of water, but they were describing what the natural causes were that were working in ponds. I think you will see I don't think very much of natural causes. We should not have been cleaning our ponds out if I did. I don't think the natural causes are sufficient; we got away from natural causes a long time ago, and the very best sort of work that has yet been done, as I look at it, is not quite good enough.

Mr. Fuller. Some reference has been made to the fact that if this organic matter is covered by a great depth of water it might be ineffective. I should like to inquire whether a depth of water over a quantity of organic matter really makes a great deal of difference.

Mr. Haskell. That opens up another subject upon which there might be two or three papers written. I don't know that anyone has yet got data sufficient enough to cover that, but there will be a

paper presented before this Association a little later, by Mr. Whipple, that I think very likely will give us some points that have a bearing upon that. Of course the organisms have got to be brought to life by some influence, either by the influence of heat or light. Of course anyone knows that a thousand feet deep they could not come to life. There is a certain depth below which water stagnates, and in some ponds at a little different depth than in others. In a very wide pond, where the wind can secure a greater leverage on the water, the point of stagnation will be lower than in a small pond. My opinion would be that any point below the point of stagnation would be sufficiently deep, and it would not be necessary to dig out beyond that point. But as far as I know, this question has never been sufficiently studied to enable any of us to talk with certainty upon it. We can simply say that things point in a certain way, and while the depth will vary in certain ponds, yet I think the point of stagnation ought to be sufficiently deep, and that we need not feel obliged to clean the bed of the pond any deeper, and quite likely we need not go so deep.

The President. In Reservoir No. 5, which we are constructing now, and which is the largest one the city of Boston has ever undertaken, instead of digging down to clean gravel and sand we are taking out about one foot in depth all over the area. I have had a great many analyses made of the soil all over the basin, and I have found that a very large per cent of the organic matter is contained in the upper few inches, so that after you get down below, say, about a foot, the amount of organic matter which you will take out is so small we have concluded to leave it and not take out all down to clear gravel.

There are in this Basin No. 5, which covers about three square miles, some large pockets, one very large pocket, of peat, and we are going to spend a large amount of money taking that out. There are two or three other places where there is peat, and there are some large areas where it is not very deep. We have recently exposed that by cutting into it, and it is very interesting and instructive to study its formation. Under the black peat, which is perhaps a foot and a half in depth, there is a brown peat which contains a large amount of silica. It is full of grass roots, and these grass roots seem to have lost all their organic nature, and are simply like little conduits, as it were, to carry the water up to the grasses. The material is very light; you take it in your

hand and it is like unformed peat. It is very clean, it is brown in color, and it is apparently of a very peaty nature until you begin to crumble it in your hand, and then it becomes very fine. As I said before, it is completely filled with these roots, which go down three or four feet in depth. Then, under this brown material, which is perhaps a foot and a half deep, is another formation with gray clay in it, and that also has the grass roots in it. Now, the question with us to-day, and one we are hard at work upon, is whether to take out this brown material or whether to stop on top of the brown. On some other occasion perhaps I may tell you what result is arrived at, and the reasons for it.

Mr. Fuller. If it had been muck down to that depth would you not have taken it all out?

The President. Yes. Of course you may have muck 20, 30 or 40 feet in depth covering large areas, and in such a case I do not think you can lay down any general rule. There are still some unsolved problems in connection with this subject. It seems to me you must make a special study of each place, and where to stop and what to do depends upon a great many circumstances. But there is no doubt that in a basin thoroughly prepared by the removal of the soil, and with gravel shores around it, the water improves very remarkably, and it is exceedingly interesting to trace the different stages in that improvement. It is only necessary to keep the water there long enough for it to lose all its color. There are streams coming into Lake Winnepesaukee which are yellow as gold, and yet the water in the lake is 0.01 on our scale, almost absolutely colorless. In parts of the lake the water is from 125 to 150 feet in depth. I have had samples taken from those deep holes and found the water just as good as at the surface. It is simply due to the fact that the water stays in the lake long enough to undergo all the changes by oxidation through the action of light and air.

UTILIZING A SPRING AS A SOURCE OF WATER SUPPLY FOR A TOWN.

BY LOUIS E. HAWES, BOSTON.

[*Read June* 11, 1896.]

Mr. President and Members of the Society:

The paper which I have to present to you introduces a subject with which we are all more or less familiar; we have all seen springs, drank of their waters, marvelled at its clearness, and often looked at the boiling water and wondered just where it originated, why it appeared there and what influences were continuing its flow after brooks and streams had become dry. For notwithstanding what knowledge we may have of the subject, there is a certain mystery lurking about it that is not easy to dispel, and probably never will entirely disappear until something better than the divining rod has been devised to trace the course of the vein and outline the reservoir that supplies the spring and preserves its constancy. The divining rod may serve its purpose in the hands of certain persons and its action appears strange, yet possibly subject to scientific explanation; however, as used it only serves to deepen the mystery and in the hands of the uninitiated is certainly useless.

Webster defines a spring as "the source from which a stream proceeds; a fountain," and the name is usually given to the particular spot where the water issues from the earth and runs off on the surface; if the quantity is small and appears at many points not well defined, the term "springy" is applied to the location.

The geological conditions governing the formation of springs in which differences of altitude bear an important part largely accounts for their rarity in flat countries. As river courses are approached and the region becomes more undulating or irregular, the conditions are improved and springs occasionally occur. The usual uniformity of the substrata, and frequent non-absorbent nature of the soil are also important features determining their absence in prairie regions. As an instance of the latter condition, the water-shed of a tributary to the Little Arkansas River in Harvey County, Kansas, may be cited, which above the point where it is utilized for water supply pur-

poses has an area of thirty square miles. Comparatively little rain water is absorbed and during a freshet the creek carries a volume measuring into the hundreds of millions of gallons in twenty-four hours, while in a dry season there is no running water for many days. Springs are seldom heard of, and the only one examined by the writer was found to be weak and intermittent in action. The soil of this water-shed is considered a little less impervious than the average in that region, for it is not an unusual condition in the West and has a marked effect upon the rivers subject to its influence. As the rainfall frequently reaches flood proportions in a short time, the water quickly travels from draw, to creek and stream and thence to the river, where the aggregation of debris washed along often entirely covers its surface, or merely permits a patch of clear water to show here and there; while the rise is rapid and considerable, and if occurring in this part of the country would be thought phenomenal.

The Verdigris River, which flows through a prairie country and empties into the Arkansas River, has a high and low water level differing by forty feet, and is one of the many rivers the soil of whose water-sheds is of this character.

Springs are also seldom or never present within large areas whose surface and sub-formation is of a uniformly porous nature, constituting locations adapted to the collection and storage of water in the ground, which in consequence of its non-confinement by any impervious inclined strata above, assumes a surface that is nearly level.

An extreme case of such formation can be seen at the broadened end of Cape Cod, where for an area of seven square miles and for a depth considerably below mean sea level the material is composed entirely of sand, through which the water moves very freely and whose character and uniformity of grains renders it almost a rival of the beautiful sand which comes from Horne Island in the Gulf of Mexico. Although hills and valleys abound no springs nor brooks exist, but there is a lake of water beneath the surface which only appears where the latter is depressed below the water table forming ponds.

Springs may be said to be present, however, on the beach at low tide when the ground water has an opportunity to escape, but they are soon nullified and stopped by the incoming tide, to appear again when the tide recedes.

Where a porous area is elevated above the surrounding country,

adjoins lower land, or is cut by streams so that the ground reservoir can overflow or find relief at a lower level, the conditions are suitable for the appearance of springs on its outskirts and we find these places their prolific feeders. Examples are found in this State in the territory called Needham Plains in the town of Needham, elevated seventy or more feet above the Charles River and composed of porous sand or gravel, and the sandy plains east of the Connecticut River in the vicinity of Springfield. The structural conditions prevalent in countries that are generally hilly are usually found to be most suitable for producing springs, and New England seems to be especially favored.

Exactly why a spring appears at any particular place is not always apparent or subject to conclusive demonstration without investigation on an elaborate and expensive scale. The most plausible and comprehensive reason that is usually given is that "the ground water in moving down a valley by the action of gravity encounters an obstruction or dam in its course which forces the water to the surface where it appears as a spring." There are other well recognized and fully as important factors which may be mentioned as follows: —

Differences in elevation between the absorbent or reservoir-forming portion of the water-shed and portions lower down, constituting the head; approach to the surface of the water-bearing strata or vein in which the water moves most rapidly, in consequence of the prominence of the bed rock or impervious strata below, or the rapid inclination of the surface above; the presence of boulders or ledge croppings at a location that is otherwise favorable, with the usual accompaniment of breaks and flurries in the stratification; and the perviousness of the overlying strata at a favorable point which offers little resistance to overcome the head.

As is very well known, the stratification of the glacial drift is decidedly varied and replete with abrupt changes; this is found to be particularly true where springs appear, so that in a consideration of the controlling influences, little more than a statement of the general nature of the soil and a suggestion as to the main elements is possible without special data.

The relations of some of these factors in specific cases is shown by the accompanying diagrams which have been prepared from information gained through the aid of test wells and excavations in the

regular course of practice, but without reference to its use for the present purpose. They represent the conditions in each place as closely as possible from the data available.

Fig. 1 is a longitudinal profile and section representing a portion of the upper part of the valley of Vine Brook in the town of Lexington, Mass. The water-shed of the brook above the point marked *c* has an area of about half a square mile, and above *b* one quarter of a square mile. The valley has no well-defined absorbent area of large extent above these points; the porous formation, of which there is a fair quantity, is distributed in small tracts on the main slopes and intervening undulations. Springs occur at the points marked *a*, *b*, and *c*, and it is interesting to note their progressiveness as the area of the water-shed increases; the one at *a* being an intermittent spring, the one at *b* a small perennial, and the one at *c* a large perennial. Pervious material is represented as shown at *d* in the section, impervious as at *e*, muck as at *f*, and rock as at *g*.

The ground water in the valley above *a* appears to be intercepted in its downward course by the impervious strata at *e*, causing it to find its way into the rock beneath, which is of a seamy, disintegrated nature, offering ample opportunity for the free passage of water and also permitting an outlet below at *b*, where the rock approaches nearest the surface and where the superimposed sand and gravel offers little resistance against the pressure that is acting upon the water.

The location of this spring appears to be determined also by a natural dam at *h* some 1300 feet away, for the line of saturation between the two points is only slightly inclined, is practically at the surface and but little below the elevation of the spring.

A marked feature of this profile is the succession of depressions containing muck deposits. The first one is four or five hundred feet long and 5 or 6 feet deep, the second one about a thousand feet across and over 12 feet in depth, while the third one is a half mile in extent and has a depth of 40 feet or more. Geologists tell us that these depressions once formed ponds or lakes and that the muck has gradually grown until the basin has become entirely filled. Our observations and soundings show that this growth is in progress in many of the ponds, lakes and reservoirs now used for water-supply purposes. Constant alluvium washings, debris, leaves, vegetable growths within the water and upon the bottom, accumulate in the muck-forming pro-

cess that promises well for the ultimate conversion of the sheet of water into a meadow.

Fig. 2 is a sectional view at the location of the Porter Spring in the town of Avon, this State. The principal absorbent area is ele-

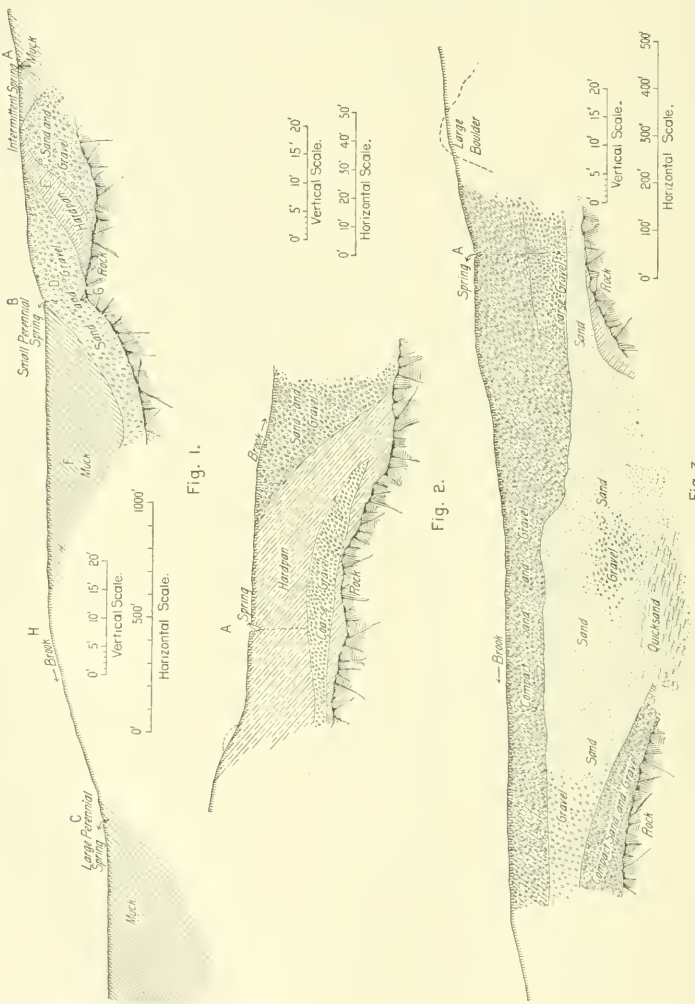


Fig. 1. Fig. 2. Fig. 3.

vated from 15 to 50 feet above the spring, is of considerable extent not far away, and the brook of the valley is about 450 feet from the spring. The water issues at the point marked a in the figure and

the principal factors determining the location, appear to be the head or pressure and the interruption or termination of the strata carrying the water which is occasioned by the impervious strata.

The water-bearing material is a coarse, reddish gravel 12 feet below the surface, which disappears beyond the spring and is overlaid by a strata of hard pan which also dips off a short distance away beneath the sand and gravel that follows. The bed rock is prominent, approaching within 16 feet of the surface and dropping off below the spring, as in Fig. 1. As boulders occur in the upper strata, weak places were no doubt present which permitted the water under pressure to force its way through. It is significant regarding the head and usual tightness of the hard pan, that when the well for utilizing the spring as a source of supply for the town was constructed, the walls were built up so as to store the water three feet higher than before, which was accomplished, and the water in the well stood five feet higher than the surface of the meadow 75 feet away, the site of the original spring having been previously sealed over.

Fig. 3 represents the formation in the vicinity of the Colburn Spring at Needham, Mass., which is an unusually large one. Although hard pan and clayey material exists in parts of the water-shed, the major portion is of sand and gravel formation of various degrees of porosity. The principal area suitable for ground storage is half to three quarters of a mile from the spring and elevated 50 to 70 feet above it. As shown in the figure, the spring appears at *a* where the bed rock is prominent, approaching within 19 feet of the surface, and a very large boulder or ledge cropping occurs a short distance above, which, as found by excavations, apparently disturbed the regularity the of stratification.

The water-bearing material is 14 feet below the surface and consists of a mixture of coarse gravel and disintegrated rock or boulders, with a finer material of a somewhat similar nature above and sand beneath, while the surface strata is compact sand and gravel. Small pockets of sand and clay were found irregularly placed at the spring location. In the valley below, a decided depression occurs in the sub-formation, which is filled with sand and gravel, varying from quicksand to fair-sized gravel. The main factors in this case are the compactness of the sand and gravel immediately below the spring, the diminution or termination of the coarse strata or vein and the great pressure from the storage reser-

voir, combined with the nearness of the water-bearing strata to the surface and the presence of malformations. There are no indications of influencing obstructions further down the valley, the brook in a distance of 1400 feet having a gradual fall of 8.5 feet.

The supply well constructed at this place permitted the water to overflow at an elevation $2\frac{1}{2}$ feet higher than the average level of the original springs, and $4\frac{3}{4}$ feet above the bed of the brook adjoining.

Where springs have been taken by right of eminent domain and the damages for so doing determined in court, very interesting questions arise as to their capacity, permanence, possibility of contamination, the value of water, relative value of the spring in question, rights of the owner to the exclusive use of its waters, and even questions affecting its genuineness, as in a case recently tried in the Superior Court for Norfolk County, Mass.

As no two cases are alike and this one has been settled, no harm can result in describing some of the salient features. The trial resulted from a suit for damages in the sum of $25,000 for the taking by the Commonwealth of Massachusetts of the Blue Hill Silver Spring in the town of Milton, which is located within the Blue Hills Park Reservation. In making an examination of the spring, its surroundings and water-shed, for the purpose of estimating its value, it was found to be situated upon the southerly side of Great Blue Hill; the water-shed having comparatively steep slopes largely composed of a stony, rocky formation, constituting a quick shed without favorable conditions for producing springs. The spring well is 43 feet from the brook draining the valley, 3 feet 6 inches in diameter and 5 feet 6 inches deep. There is no overflow, but the water moving in the same channel that supplies it issues from the ground 40 feet away as springs.

The conclusion was early reached that this water was from the surface, escaping from the brook somewhere above the spring-well and finding a channel through the rapidly inclining stony formation to appear below as springs. Measurements and tests were made to determine this, and it was found that at a point on the brook 400 feet above the springs, the quantity of water flowing in the brook equalled the quantity issuing from the springs below, plus the quantity flowing in the brook opposite the springs; showing that the brook lost an amount equal to the flow of the springs, somewhere between

the places measured and probably at a comparatively flat portion of the brook just below the uppermost point.

These measurements, together with results of a corroborative nature from other tests, demonstrated that the spring water was simply brook water a little earlier in the day, and from the nature of the intervening formation subject to practically the same influences. However, both the brook water and the water from the well were excellent in quality at the time of the examination, and possibly more suitable for table use than many waters used for the purpose that come from permanent deep-seated springs.

In considering the possibility of utilizing a spring as a source of water supply for a town, the question of purity and freedom from possible future contamination having been settled satisfactorily, considerations of the size or flow of the spring, its permanence, seasonal variations, the area and nature of its water-shed, and its location and relation to other sources of supply naturally follow. To serve as the entire supply a spring must be of unusual size, or the number of inhabitants to supply correspondingly small; when neither of these conditions is fulfilled except in a moderate degree, a spring favorably situated may be a valuable adjunct to a supply from another source, either as an increase to the existing quantity or for the purpose of imparting an improvement to the quality, which is usually the result of such an admixture.

The number of springs that may be found in nearly every town in New England is almost surprising; no less than seven of fair size were examined by the writer in one town during preliminary investigations for a water supply, so that one almost invariably hears of certain unfailing springs that "never go dry," to use a common expression, which are suggested as suitable for public use. Most of them are either too small, isolated, or unfavorably situated to be available for a town supply; but all have their enthusiastic admirers, and it is not to be wondered at, for with a spring are ever associated thoughts of an ideal drinking water.

When the possibility of having such water for every-day domestic use becomes a reality, to draw it from a faucet like common river or pond water in a large city, and at an expense of less than four tenths of a mill per gallon, instead of from three to ten cents, as is paid for table water by the jug or carboy, it is a matter for congratulation, and the community possessing it is indeed fortunate.

The size or flow of a spring depends upon the area of the absorbent surface, the storage capacity in the ground, the head or resultant velocity of the flow, and the capacity of the channels through which the water passes, but is always subject to direct variation with the rainfall. The main storage reservoir may be near or distant from the spring, but seldom or never surrounds it and is always above and usually some distance away. The water reaches its outlet through the channel offering the least resistance, which may be a very porous strata, a particularly open portion of such a strata, fissures in the rock, or the broken stone resulting from the disintegration of rocks and boulders. Where the water moves most rapidly in such channels it constitutes a vein, whose course may be very irregular, and which is therefore often difficult or impossible to find from the surface.

The capacity of a spring in its normal condition can be readily ascertained by measuring its natural flow; if these measurements are continued at regular intervals over long periods of time, including seasons of extreme conditions, the seasonal variations will be determined. Such records are rarely kept however, their importance seldom being realized until the spring is utilized and the normal conditions changed.

The capacity of a spring after its resources have been developed, or rather the capacity of the well or wells constructed for its development, differs materially from its normal capacity. The channel through which the water finds its way to any particular spring may be only one of the various outlets of the storage reservoir; the other outlets may appear at the surface as springs in other parts of the water-shed of the stream draining the valley, or may continue underground in other courses to ponds and rivers below. Consequently, when the water is drawn down at any spring to a lower elevation than that at which it naturally appears, the head is increased, causing a corresponding increase in velocity of the inflowing water, which results in a greater discharge.

When the surface of the water is first lowered, this increase in quantity may be partly ascribed to the amount stored in the immediate vicinity of the well; after a while this is exhausted, but the changes in inclination of the lines of saturation have become far reaching, and water hitherto moving in other channels is diverted by the changed conditions and follows the new inclination. If the

draught is continued the storage reservoir will be affected, its surface lowered or inclination changed, and other outlets will lose a part or the whole of their flow, which is thereby contributed to the well being draughted upon. The latter condition was illustrated during continued pumping from the Needham well while in process of construction, with occasional interruptions. The flow of the Hicks Spring half a mile away was diminished perceptibly and the action of a hydraulic ram affected, which was particularly noticed to occur when the pump at the well was in operation.

This spring is in a direction from the well nearly at right angles to the course of the brook. There are two brooks between the well and spring, the latter supplies a third and would naturally be considered in a different water-shed, although the dividing line is not pronounced. From its location and the circumstances mentioned it is probably fed by the same reservoir. It does not follow, however, that the same or similar conditions always exist concerning any two springs that may be somewhat near each other, or even in the water-shed of the same brook, for their particular water-sheds may be distinct, separated by a barrier and uncommunicable, as might be the case with two springs on opposite sides of a wide valley.

The location of the Seaverns Spring in Lexington, Mass., is an example of the latter situation, being at the toe of the slope on the opposite side of the valley from the spring wells and pumping station of the town supply, with a deep muck deposit intervening. No records have been kept that would determine beyond question that long-continued pumping on the wells does not affect the flow of the spring, but from such observations as have been made it is probable that the spring is not seriously affected, if at all.

In a preliminary study of the probable quantity to be depended upon, it would be on the safe side to consider a spring well supply on the basis of an ordinary ground water at the place under consideration, and estimate the quantity in accordance with the method described in Mr. Frederick P. Stearns' paper on "The Selection of Sources of Water Supply" under the heading "Quantity of Ground Water" printed in the journal of this Association for March, 1892.

While it is possible that a spring well as usually situated may not furnish as much water as a well located in open porous material with a direct water-shed of the same area, it is very probable that it will

furnish more water than could be expected from the same water-shed in which it is located, were the spring and its supply channels absent.

Mr. J. T. Fanning, in his treatise on Hydraulic and Water Supply Engineering, states that "From springs, with the aid of capacious storage reservoirs, it might be possible to utilize fifty per cent of the above (referring to accompanying table) volume of percolation. From wells, it would rarely be possible to utilize more than from ten to twenty per cent of the volume."

Experience teaches that the best place to secure a ground-water supply from a valley containing a large spring is at the spot where the spring appears, for where nature has already provided main arteries we may expect the freest flow and the most complete connections with different parts of the water-shed. Just what form of construction is most advisable will be determined by the existing conditions and exigencies in each case, but will not differ materially from that usual with ground-water supplies. The formation and distance to bed rock at springs is usually not well adapted to the application of a pipe well system, and a large circular well will be found best in most cases. A direct suction connection from pumps to well is more economical to construct than a conduit, and if the distance is not too great will ordinarily be found preferable for that reason. If a conduit is used it must be of ample size and built so as to utilize the full depth of the well to get the best results.

Considerations of economy in pumping, and a reserve for fire purposes other than that afforded by the customary reservoir, usually determines the advisability of additional resources before the ultimate capacity of any ground supply dependent upon a limited rate of infiltration is reached. With spring wells supplied through definite channels, the rate of inflow is largely limited by the capacity of the channels, and may therefore be slower than with a well having a direct water-shed of porous material, but for that reason the supply may be more permanent, as the rapid exhaustion of the reservoir is thus prevented.

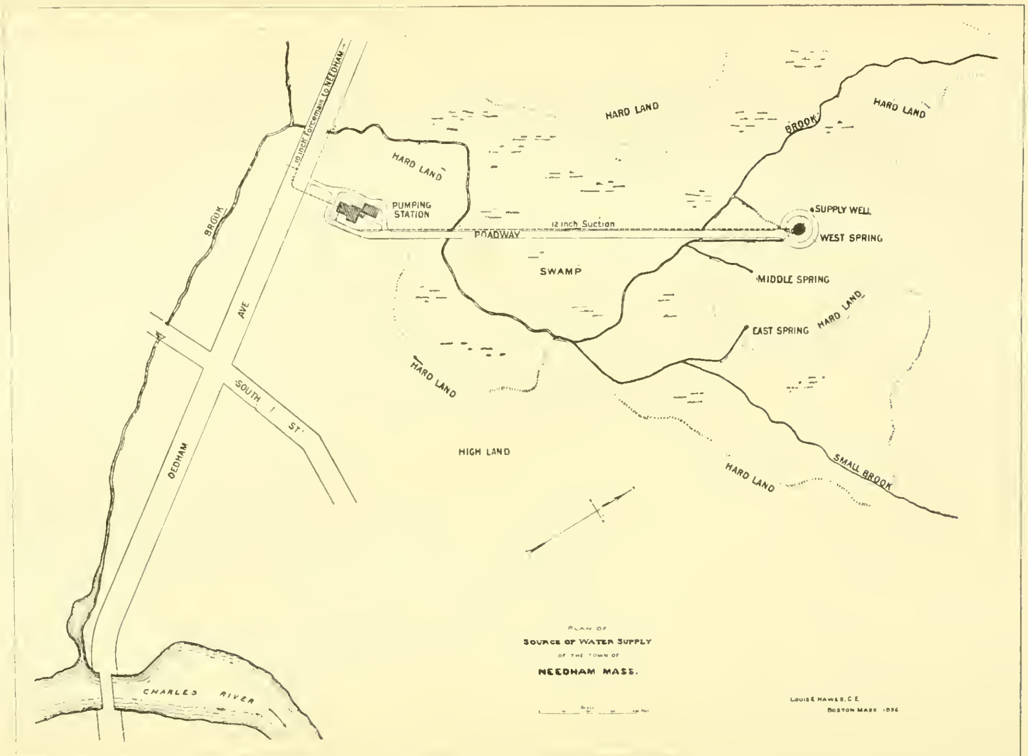
For the purpose of affording opportunity for comparison with other springs, the following data compiled from observations made before and during construction, and from the pumping records since, is given concerning two springs that have been utilized for town supplies six and five years respectively.

PORTER SPRING, AVON, MASS.

	1889	1890	1891	1892	1893	1894	1895
Rainfall (Chestnut Hill Reservoir) in inches .	54.79	50.21	49.63	42.27	46.71	38.17	45.93
Observations before utilizing spring.							
Natural flow, minimum in gallons per twenty-four hours	43,056	–	–	–	–	–	–
" " average in gallons per twenty-four hours	49,680	–	–	–	–	–	–
" " maximum in gallons per twenty-four hours	70,992	–	–	–	–	–	–
" " average in gallons per year .	18,133,200	–	–	–	–	–	–
Pumped from pipe wells during fifty-three hours' trial, in gallons per twenty-four hours	243,000	–	–	–	–	–	–
From pumping records after utilizing spring.							
Daily average for the year	–	12,982	39,945	41,168	55,124	59,728	61,921
Maximum pumping, ten consecutive days, in gallons per twenty-four hours	–	27,752	44,484	82,807	81,455	101,313	75,945
Maximum for one day in gallons . . .	–	77,589	84.811	120,045	122,974	143,970	135,531
Time pumping maximum quantity . . .	–	2h. 30m.	2h. 30m.	3h. 25m.	while painting standpipe.	4h. 40m.	while painting standpipe.
Total gallons pumped	–	4,738,609	14,580,106	15,026,291	20,120,272	21,800,682	22,601,234

COLBURN SPRING, NEEDHAM, MASS.

	1890	1891	1892	1893	1894	1895
Rainfall (Chestnut Hill Reservoir) in inches	50.21	49.63	42.27	46.71	38.17	45.93
Observations before utilizing spring.						
Natural flow, minimum in gallons per twenty-four hours	246,816	–	–	–	–	–
" " average in gallons per twenty-four hours	274,320	–	–	–	–	–
" " maximum in gallons per twenty-four hours	310,536	–	–	–	–	–
" " average in gallons per year	100,126,800	–	–	–	–	–
Pumping from well excavation continuously 21.5 days.						
Minimum quantity in gallons per twenty-four hours	415,152	–	–	–	–	–
Average quantity in gallons per twenty-four hours	440,479	–	–	–	–	–
Maximum quantity in gallons per twenty-four hours	519,840	–	–	–	–	–
From pumping records after utilizing spring.						
Daily average for the year in gallons per twenty-four hours	–	25,419	64,654	106,149	112,217	139,099
Total gallons pumped	–	9,278,008	23,663,503	38,744,726	40,959,255	50,771,384


PLAN OF
SOURCE OF WATER SUPPLY
OF THE TOWN OF
NEEDHAM MASS.
LOUIS E. HAWES, C.E.
BOSTON MASS 1896
HARD LAND
HARD LAND
BROOK
SUPPLY WELL
WEST SPRING
MIDDLE SPRING
EAST SPRING
HARD LAND
12 inch Suction
ROADWAY
SWAMP
HARD LAND
PUMPING STATION
10 inch Forcemain to NEEDHAM
HARD LAND
HIGH LAND
HARD LAND
SMALL BROOK
BROOK
AVE
SOUTH ST
DEDHAM
CHARLES RIVER

The Porter Spring constitutes the present supply for the town of Avon, Mass., having a population of 1,626. The water-shed of the brook draining the valley has an area above the location of the spring of about 0.5 of a square mile, with possibilities for a reserve supply; and the formation of a considerable portion of the territory is of a fairly absorbent nature, 30 or 40 acres tributary to the spring being especially favorable.

The table shows that during the last three years the quantity of water pumped exceeds the average natural flow as observed in 1889, demonstrating that the normal capacity of a spring is not the measure of the capacity of a well at the same location, the difference in quantity being made up from the storage reservoir. In 1894, the year of least rainfall, the quantity pumped was but six per cent of the total rainfall, indicating that much water runs to waste during wet seasons.

The minimum natural flow was measured after a period of nineteen days, when the rainfall was so slight that probably none of it reached the water table; and the maximum following a fall of 2.44 inches, showing the variations springs are subject to in direct consequence of variations in the rainfall.

The quantity pumped during a short preliminary trial of fifty-three hours was an aid in studying the source, and indicates pumping possibilities in a similar season when the storage reservoir has not been drawn upon for too long a period to permit of it; as does also the quantity pumped at a trial of the permanent pumping plant for determining its capacity per minute and steaming qualities, at which time 103,555 gallons were pumped into the stand-pipe in a run of two hours and forty-three minutes.

The Colburn Spring supplies the town of Needham, Mass., which has a population by the 1895 census of 3,511. The brook near by has a water-shed above the spring of about 0.9 of a square mile, which is particularly adapted for absorbing a fair percentage of the rainfall.

It is evident from the Needham records that the water required in 1895 was a little more than one half the natural flow of the spring, and that the maximum demand has not required a draught upon the reserve in the main storage reservoir, 251,102 gallons being the maximum pumping for one day in 1894, the year of low rainfall.

The greatest natural flow observed in 1890 was on April 10, nearly an inch of rain having fallen the day before, and the least flow on

Aug. 25, after nearly three months in which there was a deficiency of rainfall, and in a season when it is doubtful if the water table received any replenishment.

The quantities pumped from the well excavation during construction are of interest, as the pumping occurred immediately after the deficiency in rainfall before mentioned and when little or no water was running in the brook above the spring. The pumping covered a space of two and one-half months, and during three periods was continuous; one of 11 days, one of 21.5 days, and the third of 12 days, with a dry spell of two weeks occurring during the longest period. The least quantity pumped was during three days at the end of the dry spell, and as given in the table was 415,152 gallons, which amount represents twenty per cent of the average daily rainfall for the twelve months preceding.

By the third day after pumping ceased, at the end of this space of two and a half months, during which time the quantity pumped and the natural flow exceeded 23,000,000 gallons, the spring had resumed nearly its usual flow.

The Colburn Spring, originally consisting of three distinct springs within a radius of 110 feet of each other and marked East Spring, Middle Spring, and West Spring on the plan accompanying, is not far from the Charles River. This locality is near the middle of a long detour which the river makes about the town, almost semi-circular in shape, for a distance of about nine miles. The town is practically enclosed by it on three sides, the main villages being situated near the centre of the bow on elevated land about a mile from the river. The water-shed of the brook is east of the villages and comprises a portion of the Needham plains before referred to, with an absorbent area of a hundred acres or more where the formation is very porous and the water table twenty-five or thirty feet below the surface.

The location of the works is particularly fortunate in possibilities for the future, when the town outgrows the supply from the well; not the least of which is the opportunity to obtain a ground-water supply near the river; legislative right to a daily quantity of 500,000 gallons from it having been obtained by the town.

The supply works were designed with a view to future additions, the pumping station being located nearly midway between the spring and the river. This renders the connection between pumps and well longer than ordinarily advisable for a direct suction. It was

determined by considerations of the best location for the station, present and future, together with the fact that the extra friction in the suction pipe would be of little consequence in this case, as there is a back head of two feet on the pump discharge valves when the well is full, and the maximum lift is but 19 feet. The suction pipe is 12 inches in diameter, 970 feet long and laid on a true grade.

The spring well is circular, 22 feet in average diameter, 24 feet deep, built of open-jointed rubble masonry with a lining of brick laid in cement mortar, for the upper 18 feet, and is surmounted by a conical shingled roof. It was built at the largest and highest of the three springs and the sites of the other two were sealed over with concrete, while the water was kept down by pumping from the well. The outlet is a foot and a half below the top of the well which overflows between times of pumping. Access from the street is by a roadway built around the station and across the meadow.

The pumping plant is in a substantial brick building, is operated by steam, the machinery is duplicate throughout, designed for economical operation, and has a total capacity of one and a half million gallons in twenty-four hours. The plant is connected with the distribution system three quarters of a mile away by a 10-inch force main.

DISCUSSION.

Mr. Fuller. I would like to ask Mr. Hawes whether he tested the temperature of what appeared to be the spring water, in the case which he mentioned at Blue Hills, and compared it with the temperature of the brook water.

Mr. Hawes. That was one of the corroborative features. I found the temperature of the water in the well to be 42° F., which would indicate that the water came from the ground near the surface, as the temperature of springs is nearly 50° the year round. The tests were made in the winter time when the temperature was down below freezing; between zero and freezing all the time. It was also found in pumping out this well, that the temperature of the water instead of becoming higher as one would ordinarily expect with deep water, lowered a little; showing that the temperature of the water in passing from the brook to the well was raised; the temperature of the water in the brook being below that in the well.

RECENT SPECIFICATIONS FOR PUMPING ENGINES FOR THE WATER WORKS OF THE CITY OF ST. LOUIS, MO.

DISCUSSION BY F. W. DEAN.

[*June* 11, 1896.]

I have been requested by your president to discuss the specifications for two pumping engines for the city of St. Louis which have recently been issued. The specifications are the work of Mr. M. L. Holman, Water Commissioner of St. Louis, and a member of our Association. They are for vertical triple-expansion engines of 15,000,000 gallons capacity in twenty-four hours, and bear the same evidence of care and ingenuity in their preparation that has characterized all of the St. Louis specifications since 1889.

Mr. Holman has well-defined ideas as to what is desirable in a pumping engine, and the specifications are so prepared as to prevent their evasion. They are so ingeniously interwoven with conditions, and so strongly tied together, that Mr. Holman is fond of characterizing them as being "loaded." They are among the best ever issued.

In the desire to make a cheap engine a designer may think that he will design a small engine and run it fast, when he notices that the specifications say that the plunger speed must not exceed two hundred feet per minute, which is very slow. If he then thinks that he will make the plungers of shorter stroke than the steam cylinders in order to make the pumps short and cheap, and the steam cylinders small in diameter, he finds himself balked by the clause that states that the diameter of the plungers is not to exceed forty-four per cent of the stroke. He finds, also, that the minimum area of the water way through the pump valve is stated, so that he is unable to economize in valves, nor in pump cross-section area, in the vain hope of making a less costly design than his competitors. About this time the designer concludes that he will design an engine as Mr. Holman wants it.

Besides this, the successful bidder of the previous set of engines for the same place finds that these specifications differ from former ones sufficiently to prevent his using his old patterns, and thus the

work is thrown open to everybody, giving the city whatever advantage may come from this.

An acquaintance with the specifications issued for a number of engines for the St. Louis water works, beginning in 1890, shows that the Holman "idea," if I may so characterize it, is slow speed for everything, — for moving parts of the engine, and for water. This is, in itself, from various points of view, advantageous, and contributes to peace of mind. When an engine contract is open to competition, and the lowest bid is to be accepted, as is always the case at St. Louis, slow speed is comforting, for an unskilful designer is far more likely to be successful with slow speed than with fast.

In connection with this, however, it is undoubtedly a fact, that in the hands of a skilful designer a pumping engine can run two or three times as fast as the St. Louis engines are to run, and with fully as much satisfaction and durability. The secrets of this, if they are secrets, are large water ways, large suction air chambers, rubber valves, small lift of valves, and large discharge air chambers. Looking a little beneath the surface, this means quick-moving machinery with slow-moving water, and great elasticity of cushion for the water. Moreover, the elastic cushions should be as near the seat of disturbance as possible.

There is ample evidence of the truth of this theory, for there are many pumping engines, having the above qualities, that have actually been improved in working by being speeded up.

It should not be overlooked, however, that these engines can be run faster than the stated speed and thus become engines of greater capacity, which may be very advantageous to the city under some circumstances.

There is a disadvantage in making as powerful an engine as the St. Louis engines are to be, slow running, on account of their enormous size. In this case the horse-power of each engine is 900 at the steam end, which is greater than in most other cases. This requires a low-pressure cylinder nearly 96 inches in diameter of bore. If the plunger speed could be made 400 feet per minute, the diameter of the low-pressure piston could be 68 inches, which would lead to considerable peace of mind, also, especially to the foundryman who casts the cylinder.

Not a little of the interest attaching to these engines lies in the fact that they are to pump directly into the city mains, and that they

are to have relief valves to discharge their whole capacity back into the suction pipe when the mains cannot receive it.

It is customary to build a masonry foundation from the bottom of the pump up to the bedplate of the engine, but in this case the iron work is to begin at the bottom of the pit, which is 36 feet deep. This is an interesting departure from ordinary practice, but not without precedent. It is advantageous in taking up less room than masonry and in less obstruction of the light, and is probably cheaper than masonry.

After these engines are erected, all parts containing water are to be subjected to a pressure of 200 pounds per square inch. This will of course test the principal reciprocating parts, and this test is a very important feature.

The duty trial is to be of twenty-four hours' duration, and the duty must be guaranteed to reach 135,000,000 ft. lbs. per 1000 lbs. of steam consumed, which is the highest guarantee ever required, so far as I know. Nevertheless, there ought to be no difficulty in obtaining this duty.

It is well known that when engines are started large quantities of oil are used, and doubtless Mr. Holman has found that if the city pays for the oil it is used extravagantly. To overcome this expense to the city, the specifications require the contractor to furnish all oi and grease used during the first six months.

There is only one more point that I wish to refer to, and that is, if the duty of the engine falls below the guarantee, the contractor is to lose at the rate of $2,000 for each 1,000,000 ft. lbs. that the duty falls below, and is to receive a bonus at the rate of $1000 for each one million that it surpasses the guarantee.

This is due in equity to both parties, and will bear a little discussion. If a guaranteed result is not accomplished the purchaser is not receiving that to which he is entitled, and thereby is subjected to an annual expense of which he is in no way the cause. He should therefore receive from the contractor, or withhold from him, a sum of money, which put at interest will yield him the extra cost of running the plant. This will make him just whole. In other words, the contractor should lose the capitalization, at the ruling rate of interest, of the annual extra cost of running the plant, due to the inferiority of the engine.

In the other case of an excess of duty, as this has cost the con-

tractor nothing, no reason can be given for paying a bonus, but he cannot pay the whole capitalization of the annual saving produced by surpassing the guarantee, for then he would be no better off by having the better engine. He can, however, well afford to divide this equally between himself and the contractor, and thus hold out an inducement to furnish an extra good engine.

SPECIFICATIONS FOR HIGH SERVICE PUMPING ENGINES NOS. 9 AND 10, ST. LOUIS, MO.

(*The contract and general clauses are not printed herewith.*)

SPECIFICATIONS.

Work to be done. 1. The work to be done consists in making the design, furnishing general and detail drawings, constructing and erecting complete in place, ready for operation at High Service Pumping Station No. 3, St. Louis, Mo., two vertical triple-expansion condensing pumping engines. Each engine shall pump fifteen millions U. S. gallons of water in twenty-four hours.

GENERAL DATA.

Water Pressure (discharge pipe gauge)	125 lbs.
Steam " (at throttle)	125 "
Elevation Bottom Pump Pit (City Datum 100) . . .	89.56 feet.
" Engine Room Floor	117.56 "
" Water in Wet Well (Approximate) . . .	110 "
Dimensions of Pump Pit	56 x 57 "
Summer Temperature circulating water about . . .	80° F.
Winter " " " " . . .	40° F.

PLANS.

Working Detail Plans. 2. A complete set of accurate and distinct detail working tracings, made in accordance with the general plans submitted by the Contractor with his proposal to the Board of Public Improvements, shall be furnished by the Contractor and submitted to the Water Commissioner within six months after the award of the contract.

3. The tracings shall be of uniform size — $25\frac{1}{2}$ x 39 inches — and shall have a clear margin of at least $\frac{5}{8}$ of an inch.

4. The kind of material to be used in each and every part of the construction shall be clearly denoted in the tracings by different section lining or by distinct lettering.

5. The tracings shall show complete sectional outline and plan views, giving all necessary dimensions and thickness of metal, radii of fillets and roundings in the various parts of the construction in plain and intelligible figures, and shall definitely state in printed letters, at all surfaces and details, the name of the parts and the kind of machine work and finish to be put upon them, thus enabling the machinery to be built and completed exclusively from blue prints taken from the tracings.

6. There shall be separate tracings showing the valve motion complete.

7. The tracings will be examined by the Water Commissioner, and if found in accord with this contract and specifications will be approved; any change found necessary shall be at once made by the Contractor to the satisfaction of the Water Commissioner.

General Working Plans. 8. The Contractor shall also, within four months after the award of the contract, furnish accurate and workmanlike general tracings, made in accordance with the drawings submitted by the Contractor with his proposal, and filed in the office of the Board of Public Improvements.

9. These general tracings shall show the position of the engines in the pits, with all floors, girders, platforms, stairs, galleries, railing, pipes, stop valves and all appliances complete, giving all general dimensions required in the erection of the machinery.

Change of Design. 10. If, during the construction, it be found expedient or necessary to change or modify the design of any of the details of the engines, working drawings showing the proposed changes shall be submitted to and approved by the Water Commissioner before any change is made.

11. All drawings rendered in any way incorrect through changes or modifications must be completely replaced by new tracings.

Book of Finished Drawings. 12. Before the final payment for the engines, the Contractor must furnish and deliver to the Water Commissioner a book of complete general and detail drawings of all parts of the engines and appurtenances, as built and erected.

The detail drawings shall show all details entering into the construction in sectional outline and plan views, with all dimensions

plainly written in neat and intelligible figures, and names printed at every detail, the kind of material used, and the finish of the various parts and surfaces.

The general drawings shall show the engines in position in the pump pits in at least four different views, viz. : Sectional side elevation, sectional end elevation, contour or outline end elevation and plan, and shall give necessary main dimensions, thickness and kind of metals, location of foundation bolts, and all important sizes of the machinery as erected.

These general and detailed drawings shall be made on mounted double Elephant paper of a size of $25\frac{1}{2}$ x 39 inches inside the margin lines, strongly and substantially bound in book form, with the name and date of the engines printed in gilt letters on the covers of the book.

All drawings shall be accurately and neatly executed in ink, in a workmanlike manner and to an appropriate scale. All sheets shall be uniformly lettered and consecutively numbered, and provided with proper titles.

DESIGN.

General Features.

Pit. 13. The two engines shall be designed to be operated independently in the south pit of High Service Pumping Station No. 3, and aligned as shown by the plans on file in the office of the Water Commissioner.

Especial attention must be paid to the fact that the engines will be used for direct-pressure service.

14. The engines shall have ample room around all their various parts for access and maintenance.

Suction. 15. The height of the water in the wet well will depend upon height of water in conduit, which will approximate an elevation of 110.

Steam. 16. The engines shall be designed for an initial steam pressure of 125 pounds per square inch, and a water pressure of 125 pounds per square inch.

Plunger. 17. The pumps shall be designed and constructed to deliver the stipulated quantity of water at a plunger speed which will insure a smooth and effective action of the pump-valves, and all working parts of the machinery, but in no case shall the diameter of

any pump plunger exceed 44 per cent of its stroke, or the plunger speed exceed 200 feet per minute.

Balanced. 18. The arrangement and construction of the engines shall be such that they will give equal steam cards from each cylinder on the up and down strokes.

Reliability, etc. 19. The engines shall be designed and proportioned to have great working strength, stability and stiffness, and ample space around all parts for erection, repairs, lubrication, inspection, and adjustment.

Engines Self-Contained. 20. The engines shall be self-contained. That is, the bottom bed-plates shall rest on bottom of pit, and all framing be carried up with cast-iron columns thoroughly cross-braced.

Height. 21. The steam cylinders and the regulating mechanism of the cut-off and valve motion shall be placed entirely above an elevation of 120 feet above datum.

Frame. 22. The pump chambers and steam cylinders shall be rigidly connected and supported through the intervening frames and columns to make the whole construction of ample stability, strength, and stiffness.

Plungers. 23. Each engine shall have vertical steam cylinders and single-acting outside packed plungers, and no construction will be allowed requiring internal stuffing boxes, glands, or water packings in the pumps. All stuffing boxes shall be readily accessible for inspection and tightening up, while the engine is running.

Removal of Parts. 24. The machinery shall be so constructed that the pump chambers or any important part or piece can be easily removed to such position that it may be hoisted out of the pump pit without necessitating the frame and fixed parts being taken apart or removed.

Condenser. 25. Each engine shall be provided with a surface condenser, of appropriate size and construction to maintain a steady vacuum, and designed to directly utilize the water received by the main pumps for condensation of the exhaust steam.

Attachments and Appurtenances. 26. The Contractor shall furnish and put up all pipes, valves, oil cups, drip pans, fittings, and fixtures required to make the construction complete inside the engine room and pump pit, and shall make connection with steam main on east wall.

Appearance. 27. The various parts of the machinery shall be of

plain shapes and forms, adapted to their specific purposes, insuring great strength and reliability with good mechanical effects.

Frame and Fixed Parts.

Frame. 28. The framing shall be designed to have great stiffness and weight, so that it shall withstand all working stresses with the minimum vibration. All bed plates or sole plates shall have ample bearing surfaces to safely distribute the working pressures.

Anchor Bolts. 29. The engines shall be securely anchored and held in place with a sufficient number of foundation bolts.

Castings. 30. All castings shall be designed to avoid sudden changes of section, and of such forms as will cool uniformly without shrinkage strains.

31. At all flanges of castings there shall be a reinforcement, or addition of metal, of at least 30 per cent of the regular thickness, which shall extend in length or height at least twice the total thickness of the metal at the reinforcement. All flanges to be of not less thickness than the total metal at the reinforcement.

32. All castings must have good-sized fillets at all corners; no small brackets will be allowed.

Reheaters. 33. Reheaters shall be designed with proper heating area, and constructed to be absolutely steam tight under all working conditions to which they will be subjected, and must have room and facilities for examination, repairs, and renewals.

Jackets and Side Pipes. 34. Steam jackets must be secured to the steam cylinder in such a manner as to allow free and easy expansion and contraction, without causing internal leakage of joints, or derangement of any description to jackets or cylinders, or undue strains in any part; and must be arranged to insure proper circulation of steam and ready removal of the jacket water. Side pipes shall be provided with copper expansion joints.

35. All flat plates and surfaces acted upon by pressure must be substantiatly proportioned and strengthened with heavy ribs, to make them of ample stiffness and strength to safely carry the loads to which they will be subjected.

36. All handholes and manholes shall be of ample size, well fitted, and so constructed as to be readily opened and closed, and where necessary shall be provided with cranes.

37. Priming and draining pipes and valves shall be provided for filling and emptying the pump chamber.

Condenser. 38. The condensers must safely stand all working stresses to which they may be subjected, without leakage or weakness of any description.

Examination and Repairs. 39. The condensers shall be constructed to give ample facilities and room for the examination, insertion, and withdrawal of tubes and packing of joints. The tubes must be provided with perfectly tight and easily removable packings, allowing for expansion and contraction without injury or leakage.

40. The condensers shall be so arranged that the amount of water passing through, or condensing surface, can be adjusted to temperatures of circulating water, varying from 40° to 80° F.

41. Arrangement must be made for proper distribution and circulation of the exhaust steam and condensing water on the cooling surfaces of the condenser, without injurious impingement of the steam or condensing water.

42. All glands, nuts, and washers used in the condensers shall be made of composition; all bolts used inside the condensers shall be made of bronze.

Hot Well. 43. An open hot well shall be provided. The discharge of air pumps into hot well shall be above the water level.

Suction and Discharge Pipes. 44. The suction and discharge pipes shall be thirty-six inches in diameter.

45. For each engine there shall be a single suction or inlet pipe, which shall be attached to the gate valve, furnished by the City of St. Louis, shown in the plans of the pump pits.

46. The discharge pipe for each engine shall be carried up to an elevation of 113.6, and then horizontally through and to a distance of two feet from the outside of the pump pit wall, and shall be provided with a drilled flange for connection to pump main.

Air Chambers. 47. Each engine shall be provided with air vessels of sufficient capacity to insuresmooth, easy, and equal action of the pumps.

By-pass. 48. Each engine shall be provided with a by-pass pipe, arranged to facilitate draining the pump mains and starting the engines.

Relief Valves. 49. Each engine shall be provided with pressure relief valves, designed and arranged to by-pass the discharge of its pumps when the pressure on the pump mains exceeds 125 pounds per square inch.

50. The pressure relief to be of sufficient capacity to by-pass total discharge of the engine.

51. There shall be platforms or galleries of cast-iron plates or wrought-iron open work at convenient locations upon the pump and steam ends, which will allow all of the operations necessary in running and maintaining the engines to be safely and easily performed.

52. The Contractor shall design, furnish, and erect iron stairways, landings, and galleries leading from the top gallery down to the bottom of the pump pit, with all intermediate galleries and supporting girders, beams, and composition railings required to make them complete and satisfactory in all respects. All the above to be made of neat and harmonious proportions, and arranged to leave sufficient space for hoisting and removing the pump chambers and other parts of the machinery without disturbing any beams, bedplates, or other stationary parts, or necessitating the removal of stairways, landings, or galleries to any great extent.

Light. 53. The galleries, stairs, and platforms shall be arranged to secure as good diffusion of light in the pump pit as possible.

54. The stairs to be made without risers, and where practicable the tread plates and all gallery plates shall be made of a suitable open-work pattern.

All parts of stairs, galleries, and platforms shall be accessible for inspection and painting.

Mechanism and Wearing Parts.

Strength and Stiffness. 55. All moving parts shall be of ample strength and of sufficient stiffness to prevent undue vibrations in operation.

Wearing Surfaces. 56. All journals and wearing surfaces shall be of sufficient size and of proper proportion to avoid excessive pressure and heating.

Counter-boring. 57. Provision shall be made to prevent the wearing of shoulders on either stationary or moving parts at points of extreme travel.

Journals. 58. All journals above four inches in diameter shall have provisions for horizontal and vertical adjustment.

Bushings. 59. All glands and guide rings of stuffing boxes shall be provided with composition linings forced in and securely held in

place, and the glands shall be cupped out to make proper receptacles for lubricants, leakage water, etc.

Valves, etc. 60. The bodies of all valves, three inches in diameter and smaller, shall be entirely of composition, but the bodies of valves, larger than three inches, may be of cast iron, with composition valve and valve seats.

61. All valves, fittings, fixtures, and appurtenances used shall be of an approved design.

Steam End. 62. The valve motions and starting arrangements of the engines shall be such that each engine can be promptly and safely started and operated by one engineer.

Valves. 63. The steam distribution valves shall be of a known reliable type. They shall be well balanced and so designed as to work with the minimum friction, to wear even and steam tight, and to have proper facilities for refitting and adjusting.

Valve Motion and Regulation. 64. The steam valve mechanism shall be of ample strength and durability; must be reliable in all its functions and free from any danger of failure by derangement or rebounding. The engine shall be provided with an automatic device to prevent racing in case of a broken pump main.

Cut-off. 65. The engines shall be fitted with a variable cut-off mechanism so arranged as to be easily and quickly adjusted while the engines are in operation.

Throttle. 66. The running throttle valves of the engines shall be of a well-balanced type, and operate quickly and easily under full steam pressure.

Pistons. 67. The steam pistons shall be provided with Babbitt and Harris piston packing, or packing which, in the opinion of the Water Commissioner, is equally efficient. Piston rods shall be provided with metallic packing equal to that of the U. S. Metallic Packing Company.

68. Steam valves above six inches in diameter shall have steel stems provided with Phosphor bronze nuts.

Pump End. 69. The area of the suction and discharge valves shall be sufficient to insure proper filling and discharging of the pumps under all conditions, but in no case shall the total suction valve area or the total discharge valve area of each engine be less than 10 square feet.

Valves. 70. The pump valves shall be designed and constructed

to open and close promptly and quietly, shall be tight and of ample strength, and shall be especially designed for facility of repairs and renewals.

71. All stems of water valves shall be made of Muntz metal or Phosphor bronze.

Connecting Pieces. 72. All connecting, piston, plunger, and distance rods, and all movable parts, must be of ample strength and stiffness to withstand working stresses.

Guides. 73. The piston rods, plunger and plunger rods, and all reciprocating parts, shall have properly designed guides and crossheads. The crossheads shall have shoes adjustable for wear.

Boxes. 74. All journals and pins of connecting and valve rods, and of all reciprocating and oscillating rods, shall have well proportioned ends with composition bushes or boxes, and provided, where necessary, for adjustment of wear. Each link or connecting rod shall, at the different ends, have provisions for compensation of wear in the same direction.

75. All strap, solid, or box ends shall be of a shape having great strength and stiffness, holding the composition boxes securely, and giving a neat and workmanlike appearance.

Locked Nuts. 76. All nuts of pillow block cap bolts and follower bolts of pistons, all screw joints of moving parts and all keys, shall be provided with a secure locking device.

Fly-Wheels. 77. Fly-wheel or beam shafts shall rest in pillow blocks very securely and rigidly supported at ample distances apart.

Air Pumps. 78. The design and construction of the air pumps must be such that they will at all times perform their work promptly without noise or injurious shocks.

79. The air pump, boiler feed pump, air chamber supply, and all accessory pumps required to run the engine, shall be driven from the main engine. An independent air compressor shall be provided for loading air chambers.

MATERIALS.

80. All materials used throughout this construction must be of the special class and grade called for in the specifications and designated on the drawings, and shall in each case fully stand the specified tests.

Castings. 81. All castings shall be free from blow holes, flaws,

scabs, and defects of any description, and shall be smooth, close grained, sound, tough, and of true forms and dimensions.

82. All casting must be done in accordance with the best modern foundry practice, to obtain castings of the very best quality. Castings above 500 pounds in weight shall be moulded in dry sand or loam. Great care must be taken to make all castings as nearly as practicable of uniform thickness throughout.

83. No plugging or other stopping of holes or defects of castings will be allowed.

Cast Iron. 84. The cast iron used in the steam cylinders, the steam distribution valves, the barrels of air pumps and the water plungers shall be close, fine grained, hard and uniform in character, and of good wearing qualities. The cast iron used in all other parts of this construction shall be of superior quality, tough, and of even grain, and shall possess a tensile strength of not less than 22,000 pounds per square inch. Test bars of the metal 2 inches by 1 inch, when broken transversely, 24 inches between supports and loaded in the centre, shall have a breaking load of not less than 2,200 pounds, and shall have a total deflection of not less than 0.36 of an inch before breaking.

Test Bars. 85. The test bars shall be cast as nearly as possible to the above dimensions without finishing, but corrections will be made by the Water Commissioner for variations in thickness and width, and the corrected results must conform to the above requirements.

86. If any two test bars, cast the same day, show a tensile strength less than 22,000 pounds per square inch, or do not show the required cross breaking load or deflection, all the castings made from the melt from which the samples were taken may be rejected.

Steel. 87. All steel castings used in the construction shall be thoroughly annealed, and possess a tensile strength of 65,000 to 75,000 pounds, and 15 per cent elongation in two inches.

88. All steel forgings used in this construction shall be equal to forgings manufactured by the Bethlehem Iron Co., Bethlehem, Pa., and have a tensile strength of not less than 75,000 pounds per square inch of section, and show an elongation of 20 per cent in four diameters, specimens to be taken from full-sized forged prolongation, after annealing. Shafts and crank-pins shall be hydraulic forged fluid-compressed steel. All steel forgings shall be thoroughly annealed.

Wrought Iron. 89. All of the wrought iron used shall be tough, fibrous, and uniform in character, and specimens broken in the testing machine shall show a tensile strength of not less than 50,000 pounds per square inch, with an elongation of 18 per cent in eight diameters.

90. If any specimen of steel or wrought iron shall not conform to the above requirements, all material of the lot from which the specimen was taken will be rejected.

Bolts. 91. The Water Commissioner may take at random any wrought-iron bolt and nut, and have it broken in a testing machine. If any two bolts shall not fill the above stipulated requirement, for wrought iron, the whole lot of that size and make may be rejected; the effective area used in computing the breaking strength will be the area corresponding to the smallest diameter at the bottom of the threads, when cut in accordance with the U. S. standard.

Rivets. 92. Rivets shall be made from the best refined iron, and must be capable of being bent cold until the sides are in close contact without sign of fracture on the convex side.

Shapes. 93. All rolled wrought-iron shapes shall be free from twists, bends, seams, blisters, buckles, cinder spots, or imperfect edges. All sheet and plate iron must be capable of being worked at a proper heat without injury.

Rods. 94. All rods shall be formed in one continuous rolled or forged piece without weld.

Composition. 95. All the composition metal used shall consist of the best quality, new material only, of mixtures specially adapted for the work in each case, and approved by the Water Commissioner.

Phosphor Bronze. 96. All Phosphor bronze used must be homogeneous and uniform in character, and shall have a tensile strength of not less than 30,000 pounds per square inch, with an elongation of 15 per cent in eight diameters.

Muntz Metal. 97. All Muntz metal used must be homogeneous and uniform in character, and specimens broken in a testing machine shall show a tensile strength of not less than 50,000 pounds per square inch, and an elongation of 20 per cent in eight diameters.

98. Finished bolts and nuts of Muntz metal or Phosphor bronze may be tested in the same manner as specified for wrought iron, and if any two bolts shall not fulfil the requirements, the whole lot of that size and make will be rejected.

Test Bars. 99. Test specimens and samples of castings, forgings, composition, or any other material used in this construction, shall be prepared ready for testing, and supplied in the number, shape, finish, and sizes required by the Water Commissioner, and shall be prepared as may be directed at any time during the pouring or working of the materials.

For all material taken by the Water Commissioner for testing, the following prices will be paid, which shall include the cost of preparing and finishing the test specimens, viz.:

For all wrought iron or steel, the sum of ten cents per pound.

For all composition, the sum of thirty cents per pound.

For all cast iron, the sum of three cents per pound.

All broken material to belong to the City of St. Louis.

Babbitt Metal. 100. The Babbitt metal used throughout the construction must be of the following approximate proportions by analysis: 88 per cent pure tin, eight per cent antimony, and four per cent Lake Superior copper.

Rubber. 101. All rubber for valves and gaskets must be of a suitable quality, approved by the Water Commissioner before it is used.

Other Materials. 102. All other material used in the engines and not mentioned in these specifications will be subject to inspection, test, and approval by the Water Commissioner before it is used.

CONSTRUCTION.

Workmanship. 103. The workmanship and finish of the pumping engines throughout shall be equal to the best American practice, and in every respect satisfactory to the Water Commissioner.

Machine Worked. 104. All surfaces worked in machine tools must be true and smooth, and accurately conform to the drawings in shape, size, and alignment.

105. The bearing surfaces of all sole and bed plates shall be planed.

106. If fly-wheels are used, the parts shall be fitted and fastened together in the most careful and workmanlike manner, and the outer circumferences and the sides of the rim shall be turned smooth and true.

Joints. 107. All joints of bed plate and frame to be planed or faced, and carefully fitted.

Boring. 108. The steam cylinders shall be bored in a vertical position, perfectly smooth and truly cylindrical, with a boring bar of proper diameter.

Turning. 109. All circular flanges shall be faced on the outer circumference.

110. All centres of lathe work must be made of ample size and carefully preserved.

111. All corners in journals and elsewhere in turned work shall be rounded to proper radii.

Joints. 112. All steam joints shall be made in an approved manner, with a thin gasket of Jenkins' Usidurian packing.

113. All water joints to be made with approved gaskets, arranged with special care to prevent blowing out.

114. All seats of steam and water gates must be scraped and ground tight.

Journals. 115. All journals to be turned straight, cylindrical, and smooth. Particular attention and care shall be given to the proper fitting and scraping of all journal boxes, in order to make the same of an extraordinary good bearing surface and accurate fit.

Straps, etc. 116. Straps, gibs, keys, reamed bolts, bushings, and boxes of all connecting rods must be fitted with the utmost care and accuracy, and finished in a thorough and workmanlike manner.

Scraping. 117. The final fitting marks shall, for all parts, be preserved for examination, and must in all cases be satisfactory to the Water Commissioner.

118. All journal boxes, pins, keys, and other details of the machinery shall be taken apart at any time during the process of fitting or erecting, when the Water Commissioner so directs, to allow a thorough examination of fit and workmanship.

Gear. 119. If gear wheels are used in the valve motion of the engines, they shall be properly designed and accurately cut in gear cutting machines.

Cam Treads, etc. 120. The treads of cams and other parts of the valve motion subject to intermittent or sudden motion and heavy wear shall be of tempered steel or case-hardened iron.

Tempering or Hardening. 121. The tempering or hardening processes must be so conducted that parts will retain their proper size and shapes and have the requisite hardness.

Centring. 122. All parts of the engines must be well secured

and correctly centred with accurately fitted dowel pins, reamed bolts or male and female joints.

Bolting. 123. All flanges must be cast solid, and all bolt holes shall be drilled with perfectly sharpened and centred twist-drills to insure round holes. All flanges shall be spot faced around bolt holes to uniform thickness.

Dowel Pins. 124. All dowel pins must be of proper taper, and well fitted; and where necessary, shall have proper facilities for removal.

Taper. 125. All holes intended to receive tapering parts shall be carefully reemed and ground, and the tapering parts driven or forced into place.

Threads. 126. Nuts and bolt-heads and all threads shall be of the U. S. standard, except where special threads are necessary.

127. The threads and shanks of all bolts above $\frac{5}{8}$-inch in diameter shall be cut and turned in a lathe or special bolt machine, and the ends of all bolts shall be finished with neat spherical ends.

Finished Nuts. 128. Case-hardened, finished, and polished nuts shall be used in all exposed work above the operating floor, and also for all parts requiring frequent removal and adjustment. All other nuts and bolt-heads above the upper floor level, and nuts for all stuffing boxes, and at such other places as may be necessary, shall be finished.

129. Finished Phosphor bronze nuts and rolled Muntz metal studs and bolts to be used for all fastenings inside the pump chambers, and for all glands of stuffing boxes on the pump.

Cold Pressed Nuts. 130. Cold pressed nuts shall be used for all stationary parts of the pump chambers, and in all cases where not otherwise specified.

Hexagonal. 131. All nuts and bolt-heads shall be hexagonal in shape, and must be faced on top and bottom, square to the axis of bolt. The sides shall fit their wrenches accurately.

Keys. 132. All keys must be accurately fitted and properly driven or forced into place, and must be of appropriate size and taper.

133. All riveted work shall be specially designed for its particular uses, and executed in a thorough and workmanlike manner.

Calking. 134. All riveted joints subject to pressure shall be thoroughly and neatly calked with a round-nosed tool.

Finishing. 135. All connecting rods, links, and valve rods shall be draw-file finished.

136. All bright and specially finished work must be of the highest grade and entirely free from scratches, specks, and flaws.

137. All visible composition work shall have a bright finish.

138. All exposed machine-worked surfaces of all parts above the upper floor level, and of all moving parts, except fly-wheels, shall have a bright finish.

Lagging. 139. The steam cylinders, steam chest, reheaters, steam and distribution pipe and other heated surfaces of the machinery, when necessary, shall be protected by neat walnut lagging, securely fastened and held in place by brass bands and button-headed brass screws, and bright finished false covers.

Covering. 140. All steam pipes and heated surfaces shall be protected with Magnesia non-conducting covering at least $1\frac{1}{2}$ inches thick.

141. No non-conductors, lagging or false covers shall be applied until the construction has been thoroughly tested by working steam pressure, and all leakages and defects developed have been thoroughly remedied.

ERECTION.

In Shop. 142. The Contractor shall erect in his shop such parts of the steam and water ends of the engines as may be necessary, in order that the final erection can be carried on with despatch in a thorough and workmanlike manner.

Transporting. 143. The Contractor shall, at his own expense and risk, transport all parts of the machinery to the pumping station, and will be allowed the use, at his own cost and expense for operating, of the 20-ton power travelling crane in the engine house for erecting, but shall so manage the work as not to interfere with engines Nos. 7 and 8 in the adjacent pit.

144. Bed plates and castings, resting on pit bottom, shall be provided with a cement joint of proper thickness, and made satisfactory to the Water Commissioner.

145. All joints between stationary parts must be made with the utmost accuracy and precision, insuring perfect and permanent alignment. None of the parts shall be unduly strained in lining up.

Other Work. 146. The Contractor shall so conduct his opera-

tions as not to interfere with the work of other Contractors, and the disposal of his tools and materials, during storage and erection, will be subject to the approval of the Water Commissioner.

Water. 147. The party of the second part will furnish and set the gate valves in the suction pipes, but the Contractor shall pump out all accumulated water in the pump pit before commencing erection, and do all necessary pumping during erection of engines.

Protection of Parts. 148. All finished parts must be well protected in shops and during transportation, to prevent injury and abrasion.

Damage. 149. All injured parts must be replaced, when, in the judgment of the Water Commissioner, refitting will not suffice.

Cleaning Up. 150. The Contractor shall erect and remove all staging, scaffolding, trestle work for tracks, etc., needed in erecting the engines, and leave the pump pit, engine room and premises neat and clean.

Damage to Masonry, etc. 151. The Contractor shall, at his own cost, make good any damage to masonry, buildings, or other property of the city of St. Louis, occasioned by the Contractor or his employees in the transportation and erection of the machinery.

Storage of Machinery Parts. 152. The city of St. Louis will furnish space within its premises for the reception of the various parts of the machinery, but shall not be responsible for the safekeeping of these parts, nor for damage caused to them from exposure or other cause.

PAINTING.

153. All castings and details must be inspected and approved before painting, and in no case shall paint be applied until all surfaces are trimmed and thoroughly cleaned.

Paraffine Varnish. 154. All unfinished iron work not visible from the engine room floor (except where otherwise required), and that above the floor intended to be encased, shall be thoroughly painted inside and out with three coats of No. 1 Paraffine varnish, applied hot. The first coat shall be put on at the shop, and the others after erection, excepting for inside surfaces of pumps, pipes, etc., which shall receive two coats at the shop and one after erection.

Oil Paint. 155. All unfinished iron work visible from the engine room floor shall be thoroughly cleaned, filled, rubbed down, and painted with four coats of the best quality of paint with strictly pure

156. All parts covered by non-conductors must be thoroughly cleaned, and painted with three coats of Paraffine varnish.

157. All Magnesia covering, not protected by lagging, shall be given three coats of paint.

158. Walnut lagging shall be well filled and given three coats of best varnish thoroughly rubbed down.

159. All paint and varnish shall be of a color and grade approved by the Water Commissioner, and shall be applied and rubbed down to his satisfaction.

Finished Iron Work. 160. All finished and polished surfaces must be kept entirely free from rust until erected and finally accepted.

TESTING.

Pressure. 161. After erection has been completed, a blank flange shall be bolted on the out-door end of the discharge pipe, and the whole construction tested with hydraulic pressure. A force pump shall be connected to the discharge pipe, and a pressure of 200 pounds per square inch applied in such manner as to test the pumps, pump valves, air vessels, discharge pipes, pump rods, and the frames of the engines. After this test the engine is to be run to full capacity, discharging through the pressure relief valves for the purpose of testing same; a further test may be made by suddenly opening gate on pump main to test speed-controlling device mentioned in Section 64.

These tests must be conducted by the Contractor with great care and in a manner satisfactory to the Water Commissioner.

The Contractor shall furnish all labor necessary, and all piping, cocks, valves, gauges, force pumps, flanges, and appliances required in the tests.

Duty Tests. 162. For the purpose of determining the efficiency of the engines furnished under this contract, there shall be a duty test of twenty-four hours continuous run for each engine. These tests shall be conducted by the Water Commissioner.

163. The water of condensation from all steam jackets and reheaters shall be gathered and its weight carefully determined, and it shall be charged against the engines during all of the duty tests.

164. The total weight of water fed to the boilers during the tests shall be considered the amount of steam used when corrected for entrainment.

165. Steam used for running the boiler feed pumps during the duty tests will be charged against the engines.
linseed oil, and two coats of best varnish. The first coat shall be put on at the shop and the others after erection.

Speed. 166. If, in the opinion of the Water Commissioner, the speed of the engines at any time during the twenty-four hours duty test is such as to jeopardize their safety, he shall have the right to order them run at such reduced speed as will give a smooth and quiet action.

Head (h). 167. The head (h) to be inserted into the formula for computing the duty of the engines during the test shall be ascertained by attaching a gauge to the discharge pipe close to where it turns into and runs through the foundation walls of the pit, and by the elevation of the water in the wet well.

168. Any part or detail of the engines showing undue strain or weakness of any description must be replaced, and all defects developed in these tests shall be corrected by the Contractor to the entire satisfaction of the Water Commissioner.

ADDITIONAL APPLIANCES.

Wrenches. 169. The Contractor shall furnish for all sizes of bolts a complete set of wrenches for each engine, accurately fitted to the respective sizes of nuts. The wrenches for all finished nuts about the engines shall have a bright finish and shall be marked with their respective sizes.

170. Each engine shall be provided with one steam gauge graduated from 0 to 250 pounds, one vacuum gauge, one suitable steam gauge on each receiver, and one engine revolution counter ; all of them to have brass cases, triple silver plated. The dials of gauges to be twelve (12) inches in diameter.

171. Each air chamber of the main pumps shall be provided with one glass water gauge of satisfactory design. The air pump discharge of each engine shall be provided with a suitable, permanently attached thermometer of appropriate design.

172. Each steam cylinder, main and air pumps of the two engines shall be provided with permanent piping, fixtures, and motion appliances for attaching and working the indicators. All valves, cocks, pipes, and appliances for the attachment of the indicators to the steam

cylinders and pumps shall be made of composition, of ample size, and complete in every respect.

Oil Cups, etc. 173. All journals must be provided with sight-feed oil cups. There shall also be brass drip pans or pockets at all journals and oiling places to catch lubricants.

174. The steam cylinders shall be fitted with sight-feed lubricators.

175. There shall be valves, pipes, and drip pans at all places where necessary, for receiving and conveying water from stuffing boxes, etc.

176. The Contractor shall furnish at his own cost and expense all cylinder and lubricating oil, grease, and packing required to run the engines for the first six months.

REPAIRS.

177. Near the end of the year of probation, the Water Commissioner will make an examination of the engines, and any part or detail found to be defective or injured through excessive wear, over-strain, bad material, or faulty design, shall be replaced by the Contractor, at his own cost and expense, to the satisfaction of the Water Commis. ioner.

. . . .

Q The part of the first part further agree that each engine furnished under this contract shall have a pumping capacity of fifteen million U. S. gallons in twenty-four hours. The capacity to be at a speed that will insure smooth and quiet action, and to be determined by the Water Commissioner.

R The part of the first part hereby agree that the pumping engines furnished under this contract shall perform, during a running test of twenty-four hours, a duty of one hundred and thirty-five million foot-pounds per thousand pounds of dry steam.

The part of the first part further agree that in case either engine fails to perform a duty of one hundred and thirty-five million foot-pounds per thousand pounds of steam, during the duty test of twenty-four hours, ... will pay to the party of the second part, as an agreed measure of damages for lack of efficiency of the engine, in the ratio of $2,000.00 for each one million foot-pounds which the duty falls below one hundred and thirty-five million.

In case either engine exceeds, during the twenty-four hour duty test, an average duty of one hundred and thirty-five millions foot-pounds per thousand pounds of steam, the party of the second part agrees to pay to the part of the first part, as a reward for the superior efficiency of the engine, an amount to be in the ratio of $1,000.00 for each one million foot-pounds which the duty exceeds one hundred and thirty-five million.

cylinders and pumps shall be made of composition, of ample size, and complete in every respect.

Oil Cups, etc. 173. All journals must be provided with sight-feed oil cups. There shall also be brass drip pans or pockets at all journals and oiling places to catch lubricants.

174. The steam cylinders shall be fitted with sight-feed lubricators.

175. There shall be valves, pipes, and drip pans at all places where necessary, for receiving and conveying water from stuffing boxes, etc.

176. The Contractor shall furnish at his own cost and expense all cylinder and lubricating oil, grease, and packing required to run the engines for the first six months.

REPAIRS.

177. Near the end of the year of probation, the Water Commissioner will make an examination of the engines, and any part or detail found to be defective or injured through excessive wear, over-strain, bad material, or faulty design, shall be replaced by the Contractor, at his own cost and expense, to the satisfaction of the Water Commissioner.

. . . .

Q The part of the first part further agree that each engine furnished under this contract shall have a pumping capacity of fifteen million U. S. gallons in twenty-four hours. The capacity to be at a speed that will insure smooth and quiet action, and to be determined by the Water Commissioner.

R The part of the first part hereby agree that the pumping engines furnished under this contract shall perform, during a running test of twenty-four hours, a duty of one hundred and thirty-five million foot-pounds per thousand pounds of dry steam.

The part of the first part further agree that in case either engine fails to perform a duty of one hundred and thirty-five million foot-pounds per thousand pounds of steam, during the duty test of twenty-four hours, ... will pay to the party of the second part, as an agreed measure of damages for lack of efficiency of the engine, in the ratio of $2,000.00 for each one million foot-pounds which the duty falls below one hundred and thirty-five million.

In case either engine exceeds, during the twenty-four hour duty test, an average duty of one hundred and thirty-five millions foot-pounds per thousand pounds of steam, the party of the second part agrees to pay to the part of the first part, as a reward for the superior efficiency of the engine, an amount to be in the ratio of $1,000.00 for each one million foot-pounds which the duty exceeds one hundred and thirty-five million.

cylinders and pumps shall be made of composition, of ample size, and complete in every respect.

Oil Cups, etc. 173. All journals must be provided with sight-feed oil cups. There shall also be brass drip pans or pockets at all journals and oiling places to catch lubricants.

174. The steam cylinders shall be fitted with sight-feed lubricators.

175. There shall be valves, pipes, and drip pans at all places where necessary, for receiving and conveying water from stuffing boxes, etc.

176. The Contractor shall furnish at his own cost and expense all cylinder and lubricating oil, grease, and packing required to run the engines for the first six months.

REPAIRS.

177. Near the end of the year of probation, the Water Commissioner will make an examination of the engines, and any part or detail found to be defective or injured through excessive wear, over-strain, bad material, or faulty design, shall be replaced by the Contractor, at his own cost and expense, to the satisfaction of the Water Commissioner.

. . . .

Q The part of the first part further agree that each engine furnished under this contract shall have a pumping capacity of fifteen million U. S. gallons in twenty-four hours. The capacity to be at a speed that will insure smooth and quiet action, and to be determined by the Water Commissioner.

R The part of the first part hereby agree that the pumping engines furnished under this contract shall perform, during a running test of twenty-four hours, a duty of one hundred and thirty-five million foot-pounds per thousand pounds of dry steam.

The part of the first part further agree that in case either engine fails to perform a duty of one hundred and thirty-five million foot-pounds per thousand pounds of steam, during the duty test of twenty-four hours, ... will pay to the party of the second part, as an agreed measure of damages for lack of efficiency of the engine, in the ratio of $2,000.00 for each one million foot-pounds which the duty falls below one hundred and thirty-five million.

In case either engine exceeds, during the twenty-four hour duty test, an average duty of one hundred and thirty-five millions foot-pounds per thousand pounds of steam, the party of the second part agrees to pay to the part of the first part, as a reward for the superior efficiency of the engine, an amount to be in the ratio of $1,000.00 for each one million foot-pounds which the duty exceeds one hundred and thirty-five million.

ALBERT FRANKLIN NOYES,

Past President of the

NEW ENGLAND WATER WORKS ASSOCIATION.

Died October 12, 1896.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

VOL. XI. MARCH, 1897. NO. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

DRIVEN WELLS AT BROOKLINE, MASS.

BY F. F. FORBES, C. E., SUPERINTENDENT.

[*Read June* 11, 1896.]

The material for this paper was gathered from work which was done under my direction in Brookline, two and four years ago, to increase the water supply of this town.

The work consisted in laying a suction main made up as follows: 2,054 feet of 24-inch pipe, 2,093 feet of 20-inch pipe, 531 feet of 16-inch pipe, 1,427 feet of 10-inch pipe, and 155 feet of 8-inch pipe. A total of 6,260 feet, and driving 201 two and one-half inch wells, and connecting 160 wells; the other 41 wells were failures.

The plant was designed to deliver water at the rate of 5,000,000 gallons per day for as many hours each day as might be necessary to supply the town. A slight study for such a plant will convince one that it is very important that the pipes and connections should be air tight, and so put together that they will remain in this state even if some small settling should take place in the suction main; for not only does it cost money to pump air from which no benefit is received, but its presence in the conducting pipes lessens the amount of water they will carry, also decreases the quantity which can be taken from the ground by partially destroying the vacuum, and also causes the pumps to perform badly unless the air is removed before it reaches them.

It is not an easy matter to lay a long line of pipe, drive and connect numerous wells, and leave no place through which the air can flow. Not only must the material used be without defects, but the work must be most faithfully done — the latter being by far the most difficult part. It is with much satisfaction that I can speak of the results obtained in Brookline. The plant has now been in use nearly two years without giving the least trouble from air leaks, or in fact, from any other causes.

A description of the principal details of construction is as follows: the 24-inch suction main is connected directly to the pumps without an air separator, or sand receiver. The top of this main is laid from six to eight feet below the surface of the ground, and about five feet below the usual level of Charles River during the summer months. The main was laid at this depth for two reasons: first, that more water might be drawn from the ground, and second, that the main might be in the most favorable position, not to be affected by expansion or contraction due to changes of temperature. The main has a slight pitch from the pump, the further end being about six inches lower. This construction is necessary to allow any air which may be in the pipes to flow towards the station and not pocket at any point on the line.

This suction main is composed of ordinary cast iron bell and spigot pipes, laid in the usual way with lead joints. Extra pains were taken, however, in caulking these joints. During the laying of this main and the connecting of the wells, it was necessary to keep a six-inch rotary pump running day and night to free the trench from water. The bottom of the trench was a rather fine sand, and the pipe was supported on a blocking reaching to a timber platform, placed about eight inches below the bottom of the pipes, to allow room to caulk the joints.

Short cast-iron Y branches of special design were placed in the main for each well. The two and one half inch outlets of these Y branches were drilled and tapped to a templet at the foundry before tarring, under the watch of an inspector.

The wells were connected to these Y branches by two lead connections, two and one half inches in diameter and of a weight of eleven pounds per foot. A gate with companion flanges was placed between these lead connections — the flanges forming the union joint between the wells and suction main. The soldering nipples used

with the lead connections were made to order and of the best steam metal. They were delivered untinned in order that any defect in them could be easily found. Special care was taken to solder these nipples to the lead connections. A wiped joint was not considered to be always air tight, and of this size, rather difficult to make, and we finally decided to sweat the nipples in, as this process is sometimes called. The necessary heat was obtained from cast-iron plugs heated in a portable forge which fitted loosely into the nipples. The well pipes were screwed together with special wrought-iron couplings until the ends butted, and special cement was used on the threads. The wells were from thirty-five to ninety-five feet deep. Two and one half inch tees of a special pattern were placed on the wells at a proper grade to allow them to be connected by means of the lead connections to the suction main. The piping of the wells was carried to the height of about one foot above the surface of the ground and capped with a special cap. The wells have open ends, no strainers of any kind being used. In the bottom pieces, there are five rows of holes with nine holes in a row, spaced two and one half inches apart from centres, and bushed with three-eighths inch brass pipe.

As before stated, we have had no air leaks so far, and as the suction pipe is laid with lead joints, and the connection between this pipe and the wells made with lead pipe, thus making the whole construction flexible, we can see no reason why air leaks should ever occur.

The detail of the cost of construction of the work done two years ago, which included laying all of the 20, 16, 10, and 8 inch pipe, and driving 159 wells, is as follows : —

1st. The cost of driving and connecting 118 good wells, and driving and pulling up 41 poor wells : —

Cost of labor, driving wells	$1,561 00
Cost of labor, connecting wells	210 00
Cost of labor, pumping out wells	369 00
Cost of the well pipes, not including the bottom piece	572 06
Cost of the bottom piece	196 23
Cost of preparing the bottom pieces	118 00
Cost of the gate tops for the wells	360 37
Cost of the gates	660 80
Amount carried forward	$4,047 46

Amount brought forward	$4,047 46
Cost of two and a half inch tees	94 40
Cost of soldering nipples	250 16
Cost of solder	23 00
Cost of three quarter inch rope	5 31
Cost of oil	6 25
Cost of red and white lead	23 59
Cost of lead pipe	333 40
Cost of making lead connections in the shop	52 50
Cost of two and one half inch plugs	2 29
Cost of two and one half inch couplings	155 40
Cost of pulling up poor wells	80 00
Cost of Akron pipe for gate boxes	306 92
Cutting threads on pipe	206 72
Teaming	14 00
Miscellaneous	51 26
Total cost of the wells	$5,652 66
Number of feet of good wells driven	5,977
Number of feet of poor wells driven	1,741
Total	7,718
The average depth of the wells	50 feet
Average number of feet driven per day with gang of four men,	50 "
Cost of labor, driving wells per foot	$0 21
Average cost of each good well, including driving and connecting, and expense of driving and pulling the poor wells	$47 90

The detail of the cost of laying the suction main: —

Cost of labor	$10,428 32
Cost of lumber	1,118 55
Cost of the pipes	6,248 07
Cost of the gates	341 16
Cost of lead	515 09
Cost of pumping, the engineer	458 56
Cost of pumping, coal	174 71
Cost of unloading pipes	39 00
Cost of inspecting pipes at foundry and at the cars	183 00
Cost of rubber boots	210 00
Cost of shovels	52 00
Cost of carting men to and from work	947 30
Cost of hauling the pipe from the cars	300 00
Cost of miscellaneous expressing	79 30
Cost of oil for the engine	4 80
Cost of jute packing	12 74
Miscellaneous	155 43
Total cost of laying the pipe	$21,268 03

The amounts laid are as follows: —

20 inch pipe	2,023 feet
16 "	551 "
10 "	1,420 "
8 "	155 "
	4,149 feet

The total cost of laying the pipe	$21,268 03
The total cost of driving and connecting the wells	5,652 66
Total cost	$26,920 69
The total cost of laying the pipe, driving and connecting wells, per foot of suction main	$6 45

DISCUSSION.

Mr. Hawes. I would like to ask Mr. Forbes what kind of wrought-iron pipe he used for the wells.

Mr. Forbes. I used ordinary wrought-iron pipe. The bottom piece is extra heavy, with no coating at all; the idea being that if the well should stop up with rust, the gate can be shut, the cap removed, and the well drilled out. The connection between the well and the main is lead. We don't expect they will fill up, but it is easy to test the wells at any time and remove any rust which may be in them.

The President. Won't you describe the method pursued in getting rid of the rust? Do you mean you take off the cap and bore down through?

Mr. Forbes. All our wells are driven with open ends, and the holes in the bottom piece are bushed with a three-eighths inch brass pipe.

Mr. Fuller. If I remember rightly, Mr. Forbes has described at one of our meetings a method of cleaning out a well which had been driven some time.

Mr. Forbes. If the fine sand accumulates in the bottom of the well and gets above the bottom piece, of course no water can enter; and if you run a drill down in the usual way with a jet you are sure to throw most of that sand off into the ground, and it may come back later and fill up again. So I have a tool I lower down in the well, simply a jet like a water jet, only reversed (that is to say, water is pumped out of the pipe instead of into it), which screws on to the end of an inch pipe, the smallest opening being at the bottom,

so anything which gets into the pipe is sure to come through it. If a stone is small enough to get into the opening it will go through the pipe. This is lowered into the well and all the sand and material is pumped up. It is a steel pointed tool and we can churn it up and down and break up the stones.

A Member. How would that work in the case of a well ninety-five feet in depth.

The President. The water line is near the surface of the ground, isn't it?

Mr. Forbes. If the water line is within twenty feet of the surface of the ground it would work just as well; it is a question of the difference of head.

Mr. Smith. Did I understand that all of this suction main was laid below the level of the ground water?

Mr. Forbes. The normal level of the ground water is about five feet above the top of this main, but when we begin to pump, of course, the water goes down, so the whole length of the main is entirely above the water in the ground. When we start pumping in the morning at the present time the pipe is covered with water; as we pump the water goes down until the whole pipe is above the water line.

The President. You begin to draw from your reservoir, in other words?

Mr. Forbes. Yes; the water goes down into the ground. The suction main is a mile and a quarter long, and the water goes below the pipe. We have no air to pump and we have no air.

The President. It fills up again during the night?

Mr. Forbes. It fills up again during the night.

Mr. Whitney. I would like to ask Mr. Forbes why he found it advisable to use plain pipe for his wells, rather than a protected pipe like galvanized iron, which probably would not fill up so quickly with rust?

Mr. Forbes. We thought in driving the well and drilling it out while it was being driven, the tools used would be apt to injure the coating to quite an extent. And then we have found that our water has a bad effect on galvanized pipe. So we use plain pipe; and if it ever does rust all we have to do is to shut the gate, remove the cap and run the tool up and down. Probably before the pipe rusts up, it will have to be pumped any way, for wells fill up more or less.

Mr. WHITNEY. I wanted to bring out that point with reference to the difference between the two waters. We have apparently the same water in Newton that they have in Brookline, and yet for our use in Newton, galvanizing has been found to be the only successful protective coating for iron pipe, and that has been a perfect success. Service pipes which have been in from fifteen to eighteen years show no signs whatever of deterioration, and no reason why they should not last for the next fifty years.

Mr. FORBES. We cut a long thread on the bottom of our pipe, and run the coupling clear up so it is flush with the end of the pipe, that is, it is not run on half way, as is usual, but it is run entirely over the bottom of the pipe. The bottom of the pipe is strengthened by the coupling. We use cement-lined service pipes, and have, entirely, for the last ten or fifteen years. We have taken out cement-lined pipe that have been in use since the works started, twenty years ago, and you can look through them and see no indication of rust.

Mr. HYDE. Have you ever used galvanized pipe?

Mr. FORBES. We used it a little a good many years ago.

Mr. HYDE. What was the result?

Mr. FORBES. It filled right up, worse than plain pipe.

Mr. HYDE. It seems to me very strange that the difference in water taken from points so near together as Brookline and Newton should be so great. We have used a number of kinds of pipe, ordinary iron, enamelled iron, and about everything else, with the exception of cement pipe, and we find in Newton that galvanized iron pipe is the best we can use. Of course we use lead pipe to some extent, but for iron pipe galvanized iron pipe has served us the best.

The PRESIDENT. Have you ever made any chemical test to see whether there is any trace of zinc in the water, after passing through the pipe?

Mr. HYDE. Yes, sir; I had some tests made a short time ago, and found it had not affected the water; there was no appreciable amount of zinc in it.

The PRESIDENT. I have had one of those cement-lined wrought-iron pipes, Mr. Forbes speaks of, in my house in Brookline, ever since the beginning of the works, and it is in very good condition to-day.

THE FURTHER WATER SUPPLY OF THE CITY OF NEW BEDFORD, NOW BEING CONSTRUCTED.

ADDRESS BY MR. EDMUND WOOD.

[*January* 13, 1897.]

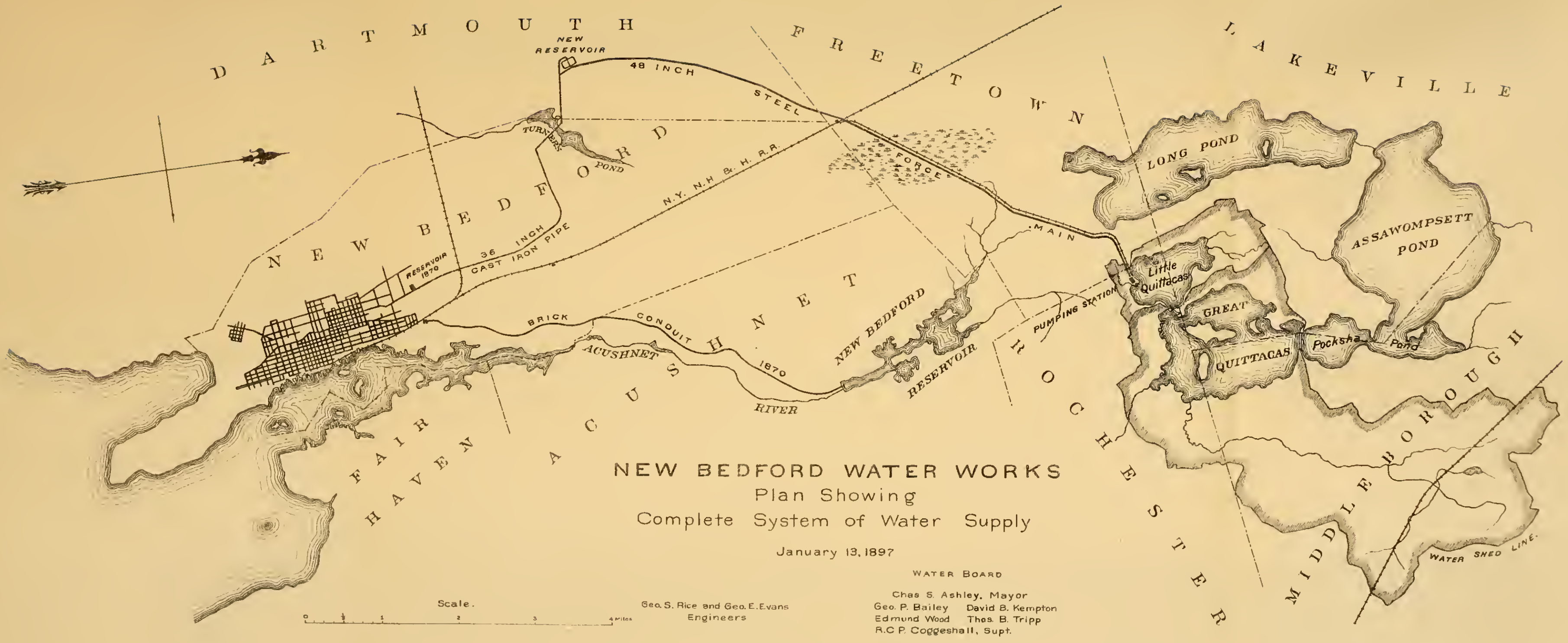
Mr. President, and members of the New England Water Works Association:

The city of New Bedford is very glad to share its recent experiences with you. They have all been new, of great interest and full of excitement to a Water Board of laymen. But in describing them to you, I must remember that you are all experts; you have all probably had your own experiences with Water Works Construction and much of it has become an old story.

I shall endeavor, therefore, to give a very rapid review of the work, dwelling only upon those things which may be of more especial interest, which are in some respects unique, or which, at least, are not common to all systems of water works. You all probably have heard of New Bedford. Our local pride leads us to hope that also you know where it is. May be the fact that this association has so long had the services of New Bedford's efficient Water Works Superintendent, Mr. R. C. P. Coggeshall, has given that town a little notoriety among you. It is of this city and its work that I shall now speak. In doing so, it might be well to describe the present system of the works, and then pass on to the changes which have been made and are being made.

Our Water Works were built very soon after the war. They were built for a maximum capacity of five million gallons. A storing reservoir was constructed near the head waters of the Acushnet River by building a dam across the valley. The bottom of this reservoir is covered with peat, leaves, and all the remains of vegetable growth. And this it is which is responsible for that beautiful light amber color for which our water is noted.

From this reservoir the water is led down to the city by an egg-shaped brick conduit built with a descent of only seven inches to the mile. At the end of this conduit in the north part of the city are



DARTMOUTH
NEW BEDFORD
FREETOWN
LAKEVILLE
ACUSHNET
FAIR HAVEN
ROCHESTER
MIDDLEBOROUGH
NEW RESERVOIR
48 INCH STEEL FORCE MAIN
TURNER'S POND
RESERVOIR 1870
36 INCH CAST IRON PIPE
N.Y. N.H. & H. R.R.
BRICK CONDUIT 1870
ACUSHNET RIVER
NEW BEDFORD RESERVOIR
PUMPING STATION
LONG POND
ASSAWOMPSETT POND
Little Quittacas
GREAT QUITTACAS
Pocksha Pond
WATER SHED LINE.
NEW BEDFORD WATER WORKS
Plan Showing
Complete System of Water Supply
January 13, 1897
WATER BOARD
Chas S. Ashley, Mayor
Geo. P. Bailey
David B. Kempton
Edmund Wood
Thos. B. Tripp
R.C.P. Coggeshall, Supt.
Geo. S. Rice and Geo. E. Evans
Engineers
Scale.
0
1
2
3
4 Miles

located a small receiving reservoir and the pumping station. The water is pumped up to the distributing reservoir on the hill with an elevation of one hundred and fifty-four feet above tide water in New Bedford Harbor.

From this distributing reservoir the water is led in pipes throughout the city.

These distribution pipes were mostly of thin sheet iron, cement lined, but they have been gradually replaced by cast iron until now but one mile of the old pipe remains.

This original system is partly worn out, and in many respects outgrown.

About two fifths of the territorial area of the city, owing to its elevation, can never be supplied by the present works. The growth of the city is now running up into these higher elevations of land which would require the construction of a high service system. We also find that the conduit has given out in a great many ways. It has to be taxed beyond what a gravity conduit of one course of brick ought to be taxed, being allowed to run full, and the roots have forced their way through the brick work, and there are numerous cracks in the arch. The growth of the city has gone out over the line, and streets have been laid out across it, and the arches have not been fortified. For some time it has been a source of great anxiety. The size of the distributing reservoir is not up to modern requirements. Its capacity is only 15,000,000 gallons, while our average daily consumption is about 6,000,000, and our maximum consumption about 7,300,000 gallons.

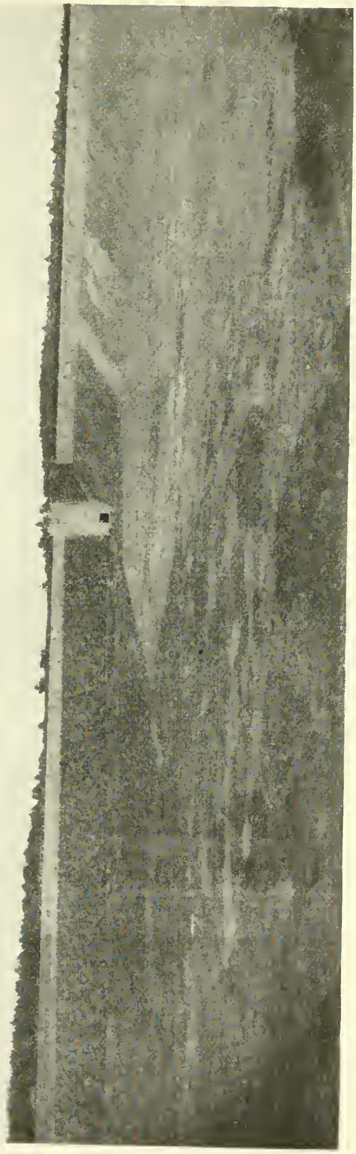
In a dry year, with a low level of water in the storing reservoir it will be impossible to get our daily summer consumption down through the conduit, and as this reservoir only has about one day's supply in reserve, we feel far from safe.

All these defects and shortcomings have gradually forced the management of the Water Department to plan extensive improvements. At different times, we have seriously considered the advisability of taking up some of these defects and remedying them. But it was a better judgment in the end which kept us from yielding to this temptation and made us decide to have the whole system looked into before we did anything. The Water Board of New Bedford secured hydraulic engineers who looked into the whole question of New Bedford's location, its possible supply, its present supply and

all the conditions that surrounded the problem, and who gave us an intelligent and full report before we decided to make any change, or do any patching. We made an arrangement with Messrs. Rice & Evans of Boston, whom you all know, and they came down and went through this work for us, and they submitted, after quite a long examination, occupying several months, a very elaborate report. They discussed this whole question; they gave us alternative plans; they suggested the possibilities of building additions, of patching the present work, but in the end they very strongly recommended a plan which was in effect the partial abandonment of the present system, at least for the present.

The question came before us in New Bedford whether we would have the heroism to begin over, rather than to make patches upon our present system. Probably this problem has come to you all. It is not that New Bedford is wiser than other places, but I think we were fortunate in the fact that we gave out in more than one part. Thus the temptation was not so strong for us to yield and begin to patch our system. One or two changes which have added a few hundred thousand dollars to the investment, make a radical change seem almost impossible. It was owing to this good fortune, that so many parts of our system needed changing at the same time, that we were wise enough to decide to cut loose from it, and begin over.

The plans submitted by Messrs. Rice & Evans to the Water Board of New Bedford provided for the taking of a new supply of water from the Middleborough ponds, to take the waters of Little and Great Quittacus, connect these waters by a deep aqueduct, locate a new pumping station upon the southern shore of Little Quittacus Pond, and force the water up a force-main, eight miles long, to the highest point found in the immediate vicinity of New Bedford. This point is not in the city, but in our neighboring town of Dartmouth. It is about 200 feet above tide water, and, by raising the reservoir, gives us an elevation of 216 feet for our water supply. There were a good many points brought up to show the superiority of this plan. It would forever take care of our high service system; the highest land within New Bedford's limits being less than 150 feet above tide water, it would give us a high enough service for the whole area of the city. This reservoir was to be constructed large enough to hold a large reserve of water, and keep a big supply constantly on tap. We decided to construct it with a capacity of



NEW RESERVOIR, NEW BEDFORD WATER WORKS, SHOWING CONCRETE LINING.

65,000,000 gallons, built in two parts with a dividing wall between. This reservoir was then to be connected with the city's present distributing system, by a pipe four miles long; this distribution pipe to be of cast iron and thirty-six inches in diameter.

This plan was submitted, as I say, by our engineers, and the question came upon its adoption. Of course, there was much discussion upon it. It seemed pretty expensive. The estimates of the cost of this work, made very carefully and itemized by the engineers, involved an expenditure of about $1,200,000, and it seemed to throw away to some extent valuable property which the city now has. In this discussion, different alternative plans were carefully considered. It was hard for us to give up the gravity system, bringing the water down by a gravity conduit. Investigation showed, however, that this would not much decrease the expense. To get so large a volume of water down to the city with so slight a descent would require an enormous brick conduit coming down the valley, built in the wettest part of the whole country, to follow the grade of the land.

After all, the plan was adopted by the Water Board, and we went to the City Council for authority to build it. The City Council adopted the plan, and went to the Legislature for its authority. They have given to New Bedford the waters of Great and Little Quittacus ponds. Great Quittacus Pond has quite a large watershed, Little Quittacus, a small one. The very finest water, according to the reports which the State Board of Health gave us, is Little Quittacus, the next the Assawompset Pond, then comes Great Quittacus Pond. But it was thought that if Great Quittacus water were brought through Little Quittacus it would give us a very perfect water. Great Quittacus is a very deep pond; we found soundings in some places of sixty feet and a good sandy bottom.

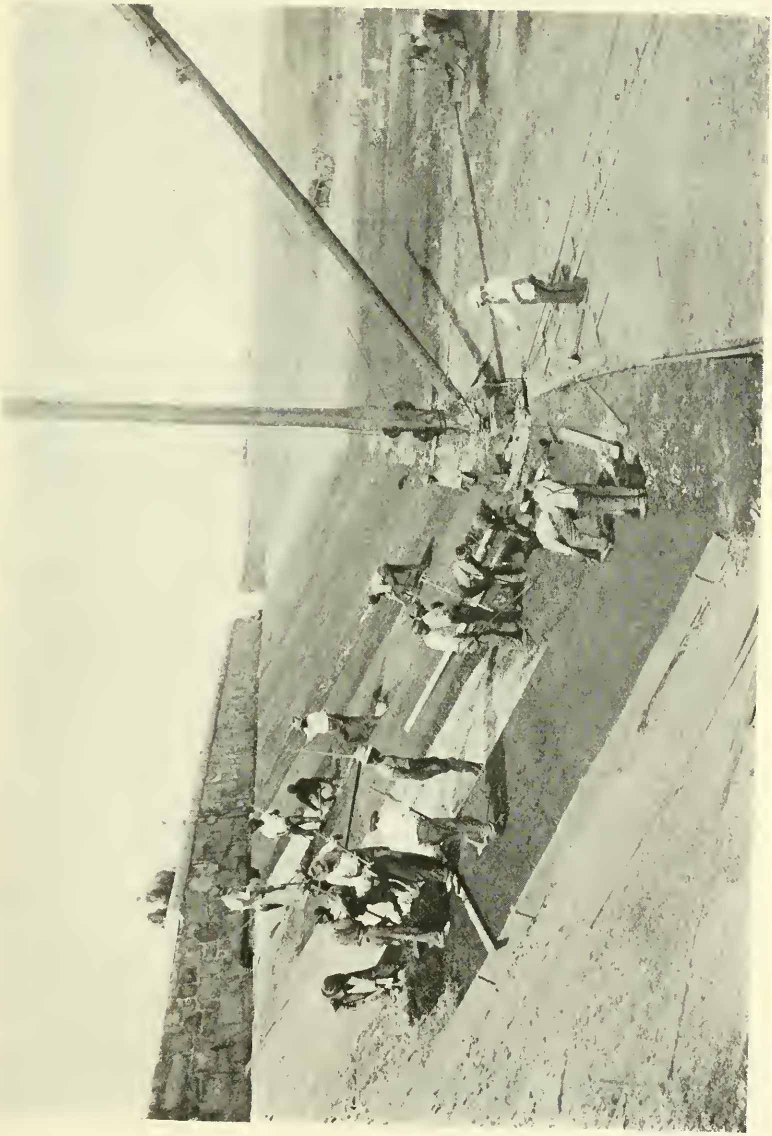
The Legislature passed the act giving authority to the city of New Bedford to take these waters, to condemn lands and build the works; to go into another township for the construction of our reservoir, in the very middle of a town road, to divert the road around it, and to do other extraordinary things. This act, as I say, was passed by the Legislature, and the City Council then appropriated this money. Then they did something which has added a great deal to the convenience of this work, and I am told is unusual in some places. They voted to turn over the whole matter of the carrying out of the act, to transfer all the powers granted to the City Council of New

Bedford by the act, to the Water Board, and they appropriated a lump sum of $1,200,000, to be raised for us as fast as we asked for it, to be expended by us, and the only check put upon all this was that we were to render an account, not of what we were doing, but of what we had done, a wholly *post facto* report, made every three months to the City Council, of the progress we had made in the work. This very much increased the responsibility of the Water Board. They will not be able to say that they were hampered in any way in their decisions of what was best by the Council entering in and deciding differently. We have had every advantage in carrying out the plan of the engineers, of working with a small executive body with frequent meetings and intimate discussion.

This plan was immediately begun. The Board continued Rice & Evans in their capacity as the engineers, and they have elaborated this system which I have described to you, and have furnished all the engineering service and the plans, and have had practical charge of the work. The original scheme has been changed, of course, in some details, but I am very glad to state here what is a tremendous satisfaction to business men, that the carrying out of these plans has been very satisfactory; that we have had to make very few changes, and the contracts have been completed so far very close to the original plans and specifications. We have not had the embarrassing questions of extra work and changes, and the endless disputes into which they lead.

This plan can be further described. The reservoir is a little different from some others which have been built. The excavated earth was found to be exceptionally good, but we have been very careful, very conservative, may be, in providing for an absolutely tight reservoir. The embankments have been built very slowly by very gradual layers of earth, only five inches thick, and under a very rigid inspection, sprinkled, and rolled with steam road rollers, and then another five-inch layer, and so on until the proper height was reached, then excavated, after it had thoroughly settled, for the retaining wall, which has been built in, and then the embankment carried up above. This has made an extremely sound, tight embankment. But we have gone to a further expense,— covering the whole surface of the reservoir with concrete, six inches deep on the horizontal portions and nine inches thick on the embankment. This reservoir is now completed, with the exception of the gate houses,

NEW RESERVOIR, NEW BEDFORD WATER WORKS, SHOWING CONSTRUCTION OF CONCRETE LINING.



NEW RESERVOIR, NEW BEDFORD WATER WORKS, SHOWING CONCRETE LINING ON SLOPE OF EMBANKMENT.

48-INCH STEEL FORCE MAIN, NEW BEDFORD WATER WORKS. CUTTING OFF PILES FOR FOUNDATION THROUGH SWAMP.

48-INCH STEEL FORCE MAIN, NEW BEDFORD WATER WORKS. PIPE READY FOR TESTING.

and we shall be very glad to show it to any of you who would be interested in a further examination of this portion of the work. We have taken the water into the reservoir on the middle of the east side and taken it out on the middle of the west side, looking out for anchor ice, which has sometimes bothered us in New Bedford. We have a by-pass which runs round the reservoir through which we can pump. We have it arranged so we can take water out of either half. We have built a very strong dividing wall, which we think is heavy enough to allow one part of the reservoir to be used at a time. This will facilitate the important cleaning of the bottom occasionally. The dividing wall is built of such a height, that, when the reservoir is full, the water will flow over the top of it and appear as one large sheet of water.

The next point in the construction, which will be of interest to you, is the force main. The engineers recommended that this be built of steel pipe. Some of our members are pretty conservative, and we believed in cast-iron pipe. This matter was pretty thoroughly discussed. It is a 48-inch pipe, and we obtained careful estimates of the cost of this pipe, both in cast iron and in riveted steel. We tried to get authoritative opinions in regard to the life of steel pipe. They varied very much in proportion as to whether you asked a friend or an enemy of cast-iron pipe to express an opinion. [*Laughter.*] But in the end we thought it the extreme of safety to figure twenty years as the minimum life of a steel pipe, when careful attention is paid to the coating. On that basis we can compare the cost of a 48-inch steel pipe with the cost of an iron pipe of the same diameter. The difference in cost, if put at interest, will amount to enough in twenty years to pay for an entirely new steel pipe. This strong argument added to others brought up by our engineers, influenced us in deciding upon steel pipe. But we concluded to have it of good thickness — $\frac{5}{16}$-inch plates.

Another question which was very interesting to us was the rather original scheme offered to us by our engineers, that this pipe should be built differently from any other pipe of which we had ever heard. That is, that it should not be constructed with telescopic joints, as most such pipes are, but with butt joints, with strap on the outside, and with countersunk rivets, giving an uninterrupted inside surface for the flow of the water. This was considered by the Board; the alternative plan being the use of the regular telescopic joint. This,

as I say, was a very interesting proposition to us, and we went into it quite elaborately, and were quite undecided which to take. We were interested in this idea of a smooth pipe. We had the opinion of many boiler makers, who thought that a pipe could be built as strongly with that method of construction, with butt joints, as with telescopic joints. We judged and we received corroborative opinions that the butt joint pipe would cost considerably more than the telescopic joint. We received bids on both methods of construction, and the cost for the whole eight miles and more of 48-inch pipe, built with smooth butt joints, exceeded the cost of the telescopic joints a little over $20,000. The Board decided in the end not to use the butt joint, but to use the telescopic joint. We do believe that that other plan has a great deal of merit. It would certainly allow a larger body of water to flow through, and consequently the pipe could be reduced in size.

Then the question of coating came, as it comes to you all who are building this kind of work, and we considered different processes. Some of them which we looked into were very interesting and seemed to provide for a great lengthening of the life of the pipe, but in some work which we saw, we could not help giving most of our attention to the places where the coating would inevitably get knocked off. When the pipes are shipped by rail from the place of manufacture and unloaded and teamed in such heavy sections, thirty feet long, it is impossible to keep them from being knocked, enough to break any ordinary or extraordinary coating on the outside. Of course the strength and the durability of the pipe would not be much longer than the weakest place in it, and there are so many places in the expensively coated pipe which would have to be patched in the trench with ordinary material, that we decided to have our pipe thickly coated with the regular asphaltum mixture, and then give extraordinary attention to the patching of the coating during the process of laying. This has been done. The pipes have come coated in asphaltum, and they have been very carefully and often painted with P. B. paint until after the final testing and covering of the pipe. This pipe is also subject to a heavy hydraulic pressure test before it is covered with earth.

The next point of interest is our railroad. The line of the force main is crossed, about half way, by the main line of the New York, New Haven & Hartford Railroad. There is one important problem

which interests every one connected with water works, to get the coal at the very lowest price at the pumping station, and the question came up as to the advisability of building a railroad. We figured up the cost and the interest upon it, and the saving in the price of coal over any other method of getting coal out there, and it seemed as if we could hardly save the interest on the cost of the railroad. But another point came into the calculation which affected our decision. This force main goes through a very bad section of country. It crosses the very large and hitherto almost impassible Bolton Cedar Swamp. You can here drive a pile fifteen feet at almost one stroke of the hammer. It was a pretty bad place to get through and put a pipe line. It was found by estimates made, that quite a portion of the cost of building a railroad could be charged off to construction account. That is, that a line of pipe built through such a territory could be constructed for a very much smaller cost with a railroad paralleling it. Then, of course, we figured upon the fact that the material for the pumping station, the engines and the superstructures, would also be carried by this railroad, if built. At length it was decided advisable to build a regular standard guage railroad from Braley's Station on the New York, New Haven & Hartford Railroad to the pumping station at Little Quittacas Pond. This railroad was one of the first things built, and is now being used to help the construction of the force main, which runs along beside it. There were no land damages on this railroad, as a strip five rods wide through that whole country was taken for the pipe line. The idea, too, is to carry this railroad right into the pumping station. At the end it passes on an elevated trestle into the coal shed. The coal, after being delivered on top of the trestle by the railroad, passes down hill all the way to the grate bars. This coal shed is to be built large enough to take in a full cargo of coal, so that a cargo landed in New Bedford can be run up and be placed in this shed without much trimming or handling. In this way we have the coal at the point of consumption at a very moderate price.

The contracts have been let for the placing of the engine foundations, and we are now about to put out the contracts for building the superstructures on the shores of the pond.

The usual vexed question came to us, too, about an engine and pumps. We seemed to incline towards a specially designed engine. Perhaps we were influenced in this decision somewhat by the fact

that New Bedford, a few years ago, built a bridge, and it was in the form of bidding that every contractor should submit with his bid the plan he proposed to build. There was an attempt made to compare them, and the contract was awarded and the bridge was built, but it would take a very courageous County Commissioner in New Bedford to ever build another bridge after that system of bidding. We decided to have an engine drawn, and then to have the bids all made upon one basis for comparison. We therefore made an arrangement with Mr. Leavitt to design two 10,000,000-gallon engines. He has prepared plans and they have been put out for bids, and the engines are now being constructed. In the contract for them, we have put in a forfeit for each day's delay in delivering them, and a proportionately liberal premium for completing the engines and pumps in less than the specified time. The first engine is to be ready for regular work in twelve months from the date of the signing of the contract. And the second engine in sixteen months.

One other point which will be as interesting to you as any in the work of our further water supply is the position we have taken in regard to maintaining the purity of the water. This came up very early in our discussions how we should do this, and a strong opinion developed among us that we should take every possible precaution, even to the absolute ownership of the shores. But there were a great many difficulties in the way of doing this, the main one being the cost. Our new supply is in a picturesque country, and cottages had begun to spring up around some of these ponds, and the value of the land would soon be on the increase. We thought with the present values of land there, that we could well afford to buy it, provided we did not have to pay an inflated price for it. We had heard often enough of the way in which some cities have had to pay for land, — of the way in which all cities have to pay for land when it becomes known that a municipality is the purchaser, and we tried to conceive of some plan by which we could acquire this territory for the regular going market rate. This was quite a problem to solve, and we tried it in various ways. One difficulty was the fact that we had no money for this purpose. All our money was appropriated to carry out the plan which was submitted to the City Council with the itemized estimate, and that only allowed of an expenditure for lands necessary for construction along the line and for the pumping station, etc. It was at last suggested that as we were so confident that this

would meet with the favor of the citizens and they would back us up in it, we might do it on our own personal responsibility, and we considered seriously the plan of going to the banks and negotiating a private note to raise $50,000 or $60,000 and to begin the work. Some of the members of the New Bedford Water Board are treated with great respect at the banks. [*Laughter.*]

This plan seemed to have much to commend it, and we came very near following it, but at last we came to the conclusion that it was a pretty risky thing to do. [*Laughter.*] In the present state of public opinion in regard to municipal officers, it would be almost impossible to do a thing like that and to pursuade the ordinary critical citizen that this land conveyed to private individuals for the purposes of New Bedford, and afterwards reconveyed to New Bedford, that some portion of it, some residuum of value did not adhere to the fingers of the men who handled it. [*Laughter.*] This was quite a convincing thought, and we gave it up. We accomplished the same purpose in another way, and as a great many of you are probably municipal officers, I will describe the way we did it. If we went to the City Council and asked for the money for this purpose, the intention of the city would be immediately advertised to every owner of land in the neighborhood. But if we could keep the expenditure quiet for three months, acting through unsuspected agents, we could secure possession of a large part of the land at fair prices. The Mayor of the city is *ex-officio* a member of the Water Board, the Treasurer is *ex-officio* the Water Registrar, and when we all became convinced that was the proper thing to do, we went ahead and did it. We bought the land secretly through agents and we quietly passed the bills and the Mayor approved the special audit and the City Treasurer paid it. [*Laughter.*] It was a source of gratification to us that such high-handed procedure was so unanimously approved, that the action of the Water Board in going ahead and buying the land in such a way was commended. It is rather an unusual course and I do not know that it can be recommended. [*Laughter.*]

We began with small ideas. We did not know what other cities had done in this regard. When we were pretty well along it strengthened us in our judgment to hear that in the city of Nashua, Mr. Holden, at the head of a private water works corporation, bought up their water shed. If it were prudent and advisable for a dividend-paying private corporation, it was a good move for a city to acquire

the title to the land actually bordering upon the source of supply. I go into this phase of our work quite fully because of the interest it has aroused in the expert on my right, Professor Sedgwick, and I am very glad to see that New Bedford's action is approved by such an acknowledged authority as he. The city had been using the waters of little Quittacus Pond for some time, and had taken no steps to acquire the land bordering on that lake, so the people down there never thought that it was a part of a water scheme to take the land.

One piece of good fortune aided us very materially. There was a gentleman who had lived on the shores of Great Quittacus Pond, who had conceived the idea of controlling this pond himself. He had begun to acquire the lands, and had become the owner of quite a portion of this shore by actual purchase. He had pursued this object as his hobby, in one sense, and with great earnestness until he had secured options on quite a number of other lots along the shore. Mr. Turner's views were most commendable. He strove for the fullest protection of the shores from an æsthetic point of view. He had a very modest cottage on the north end of the pond, and all his options had in them the provision that no wood should be cut, and no little buildings should be put up within sight of the shore. You can conceive that this sort of an idea was in exact sympathy with the object of the New Bedford Water Board, which was to get possession of all the land before the trees were cut off, and to preserve it as it was. This gentleman had made good progress in acquiring the shores of this pond when he unfortunately died.

We then paid a call on his attorney and agent, Mr. Henry A. Wyman, a Boston gentleman whom some of you know. We made a very fair deal with him for the estate's lands. The City of New Bedford told him very frankly what they wanted of this land, and were met as frankly. But the estate only owned a comparatively small portion of this shore right, but they possessed valuable options on others, which might have lapsed, the estate not caring to go on with this idea. We made an arrangement by which this gentleman acted as our agent in going around and closing up these options for us at the old original prices which had been arranged, before any city loomed up in sight as a basis of value. These lands were, therefore, purchased by him before there was anything made public. Then other lands were bought in a similar way, and when the fact was disclosed that it was the city which was buying all this land, we

had acquired three fourths of all the shore on both ponds. We then thought that this action had gone far toward fixing what was the normal standard value of such land in that locality, and that there was not much danger then in letting it out and dealing with the balance of the owners in an open way. But it was a grimly humorous fact when it became noised abroad that the powerful and infinitely rich city of New Bedford was really the party who had been anonymously and mysteriously buying lands about the pond, how immediately the value of all the remaining land went up. Some of the farms, whose owners had really offered them for sale only a year or so before, in order that they might go out West unincumbered, and build up a new farm out there more fertile than this, immediately jumped in value. The owner felt that he was bound closer than ever to this land of his ancestors, and that nothing could sever the strong heart bonds he felt for these lands except a good, liberal payment of money in the first instance, and secondly, a liberal payment for our wanton destruction of his sentiment and love of home. [*Laughter.*] But we found soon that this proposition, like a great many other propositions, was subject to a liberal trade discount. [*Laughter.*] This may sound a little heartless stated in such a bald way, but not to a body of gentlemen as familiar as you are with a city's usual experience in buying land. Of course, we have always calculated to pay the full market value for all land, and most of the prices paid have been extremely liberal, but not inflated.

The remaining land is now being acquired, and we find that it is to a great extent true; that the values now fixed by these previous purchases does govern, to a certain extent, the value of the remaining land. We have bought around these ponds, already, about one thousand two hundred acres, and we have paid for this land about fifty-three thousand dollars, and this includes some ten buildings, houses, and barns, and some quite ambitious ones, which we also had to buy.

The land varies in depth from the pond. One piece is only about 320 feet deep, and some is 2,800 feet deep from the ponds. There were cases, of course, where we could buy the whole farm just as cheaply as we could buy a few feet of front. Where a person overvalued the frontage of his farm on the pond, and would not sell it for less than he would sell the whole farm and emigrate, in some cases we did buy the whole farm. We had the remarkable experi-

ence in two cases of having a man charge an exorbitant price for the portion on the pond, of then buying from him the whole farm for only a little more money, and after a month of having the man come back to say that he had changed his mind, and wanted to return and live there. And he bought back from us the part that we did not want [*Laughter*], and at a very fair price.

This, gentlemen, is a pretty rapid and not very brief review of the work which has gone on in New Bedford toward getting this further water supply. We hope that it will stand the test of actual experience. I think we all dread the I-told-you-so kind of critic, who, after the lapse of ten years, may be, and standing in the full glare of what is then actual knowledge, will think it funny that we could not have foreseen such self-evident results as he sees then. We have had to settle a great many engineering questions, and I have stated the decisions we arrived at. But we are not so full of conceit as to believe that we have settled these questions for you or for the world. Some of these disputed questions will probably continue to be mooted in spite of what has been done in this remote corner of the State. We have builded as well as we knew, we have been assisted and to a large extent guided by our broad, sagacious, and admittedly level-headed engineers, and we have striven to turn over to the confiding City Council of New Bedford and to our liberal citizens, a work which shall stand the real test which we all care about, the test of actual use, and which, when completed, although constructed by a municipality, shall represent as nearly as possible the full cash purchasing value of the money which it has cost. [*Applause.*]

DISCUSSION.

Mr. Fuller. I would like to ask Mr. Wood what was considered the life of cast iron. He has told us that they finally concluded if the steel pipe would last twenty years, it would be better to use that.

Mr. Wood. Mr. President, I can only answer that like the man who at the age of sixty years set out a locust post to find out how long it would last in the ground. [*Laughter.*] We did not find anybody who was able to say from actual experience how long a cast-iron pipe of that diameter and necessary thickness would stand in such a place as that. It would be a great many years.

When you stop to think of the way we ultimately settled that question, it does not matter, for if the difference between the cost of iron and steel would allow us to build of steel and throw it aside and build another of steel every twenty years, we could go on having steel and probably have a new one just at the time the cast-iron pipe would have worn out. [*Laughter.*]

The PRESIDENT. Mr. Evans, the engineer of this work is present. I should like to hear from him in connection with the work.

Mr. EVANS. One thing that caused us to settle on steel pipe was its lightness. Cast-iron pipe in 12½-feet lengths weighs from four and a half to five tons, and in the country where this pipe is laid we are not close to any highways, and those which are convenient are very poor. The whole line is across country, as you might say. With the exception of crossing the highways, the line is nearly a a quarter of a mile from them, and to get cast-iron pipe on to the location, a road would have to be constructed for that purpose.

There was one thing that you might get a wrong impression of from what Mr. Wood said in regard to how the pipe is made. It is not made exactly in accordance with the boiler principles. A boiler is usually made with a small section and a larger section. These sections are all one size but taper and are inserted regularly, so that the force of the water never comes against the bevel edge of the plate inside. The larger ends of the rings of the pipe are towards the pumping station, and the smaller rings, which are ⅝ inch less in diameter, are towards the reservoir. The smaller end is 4 feet and the larger 4 feet and ⅝ of an inch, inside diameters.

The difference in cost, if I remember correctly, between the cast iron and the steel for the same length was about $138,000 in favor of steel, and taking that into consideration, and the lighter weight, we thought better to recommend the steel.

The coating that Mr. Wood spoke of, we have very little difficulty with on the inside of the pipe. The pipe was delivered coated very nicely inside, but the outside of the pipe is more or less liable to injury. The greatest injury comes from car stakes. The pipes are loaded in two tiers of four thirty-foot sections, per car, and in going down the steep grades from Pittsburg east the pipes will slip more or less, say six inches, and in a great many cases they nail blocks between the top end of the car stake and the pipe, and they scrape off the coating for a space of three inches wide and six or

eight inches in length. As soon as we receive them, if they show any signs of rust it is thoroughly scraped off and covered with P. B. paint. At the field joints the coating is burned off while they are driving the joints. That has to be gone over with paint on both sides before the water test is made. After the sections are laid and thoroughly calked, they are tested by a 250-pound water pressure, and any leaks that show are calked and the places painted over afterwards. Up to this time we have not had any stream of water from them large enough to show in a photograph.

Mr. Stearns. I would like to ask Mr. Wood whether the bids for cast-iron pipe and steel pipe were on the same diameter, or the same carrying capacity?

Mr. Wood. Mr. Evans can answer that better than I. We did not receive bids for cast-iron pipe, but in looking for information to guide the Board, we received estimates on both kinds of pipe for comparison. Mr. Evans can answer better as to the basis of comparison.

Mr. Evans. I think the Board asked us to compare the same diameter of cast iron with steel, and my impression is that it was done on the same diameter of pipe. This pipe line differs from the East Jersey in the way the plates are put together. Each 30-foot section is made up of five sections of steel plate a little over six feet each; each of which fits inside of the next, going in the way in which the water flows. In the East Jersey line there was a small section, and then a greater section, and the current of water comes against the bevel edge of each plate on the smaller sections.

Mr. Garrett. Mr. President, I am not quite clear that I understood Mr. Wood in regard to the interest on the difference of cost. Do I understand him to say that the difference in cost, which Mr. Evans said was $138,000, put at interest for twenty years would pay for a new steel pipe line?

Mr. Wood. I was of the impression the difference was a little more than $138,000 between the cost of one and the cost of the other. The difference between the cost of the steel and the cost of the iron pipe, if put at interest and compounded, as it naturally would be, would provide, at the expiration of twenty years, a sufficient sum to put in a new steel pipe. Of course, the life of this pipe would be greatly determined by the care which was taken in its manufacture, and that point I did not touch upon in my review of

this question of the relative values of iron and steel pipe. If we were extremely careful in our inspection of the steel pipe, of course it would last a great deal longer than it would otherwise. So, I might mention that as an additional precaution taken to insure the correctness of this decision of the comparative values, the manufacture of the steel pipe has been rigidly inspected at every stage. The Pittsburg Testing Laboratory have analyzed the metal continuously, as it is rolled at Homestead. Every plate is then carefully inspected. We have inspectors of the riveting and caulking in the shops, and then, finally, in New Bedford a corps of inspectors watch the laying, the riveting, and the testing in the trench.

And we have been led to believe, from those who have experience on other similar work, that the life of this particular steel pipe line will be much more than twenty years.

Mr. Garrett. It was a matter of interest to me whether there was really enough saving on the difference between the price of steel and the price of cast iron to build a new conduit, say roughly estimated at $250,000. If that is the difference between cast-iron pipe and steel, I think the cast-iron pipe makers better go to making steel. [*Laughter.*]

Mr. Cook. I would like to state that I examined last fall a 20-inch main, uncoated, which had been down 30 years at Salem, and with the exception of a little corrosion on the inside, it was practically as good as ever. We had the Smith Tapping Machine Company come to inspect it, and they guaranteed that they would make the tap in twenty minutes, but it took them an hour and a quarter to make it. There was a thick layer of rust on the inside.

Mr. Coffin. Mr. Wood stated, I think, that in comparing the two kinds of pipe, the butt-strap pipe and the telescopic joint, it was considered the telescopic would have to be made of a larger diameter to make allowance for the friction, owing to the joints and the rivets, and Mr. Stearns asked Mr. Evans, whether a similar size of cast-iron pipe was figured on for the same reason. Now, I would like to get an expression of opinion as to whether in the course of a number of years, and as time goes, the pipe gets dirty and the discharge decreases,— and perhaps the most critical point of a pipe in its capacity is after the discharge has decreased,— it would make any special difference in the steel pipe, whether the rivets were countersunk and the joints butted or not. It has occurred to me that after

15 or 20 years the tuberculation would bring them all down to about the same carrying capacity.

The PRESIDENT. I would like to have Mr. Brackett give us some ideas on that subject.

Mr. BRACKETT. Mr. Coffin has raised a question to which I have not given much thought, but it is one well worthy of attention.

In regard to the general question of the use of steel or cast iron, I think that the conditions in each case must be considered in deciding which it is advisable to use. The advisability of using steel or cast iron was very carefully considered for the Metropolitan water supply, upon which I am now engaged, and for our work it was not thought advisable to use steel pipes. The conditions, however, were very much different from those existing at New Bedford. Our pipes were to be laid in public streets where the chances of injury to the protective coatings were very much greater than they would be if laid in property belonging to and under the control of the Water Department. Furthermore, we do not desire in the course of twenty, or even thirty or forty years, to relay the pipes. It is very difficult even now to find a place in the streets to put one pipe, and it would not be practicable to take up the one we had in use to lay another, and it would not be possible to find a place to put the second one. These two reasons alone would have led us to use cast-iron instead of steel. On the other hand, where a city owns a right of way, where in twenty years they can replace the pipe, it may be advisable to use steel.

Mr. COOK. There is one thing that has been a conundrum to me. In Salem we have 6 and 12 inch pipes on bridges for distances of one or two hundred feet with no packing at all, and they never freeze. Now, I do not understand why it is necessary to lay 48-inch pipe so deep as they do here in Boston.

Mr. BRACKETT. The 48-inch pipes are placed, where possible, three feet below the surface.

Mr. COOK. Aren't the trenches about nine feet deep?

Mr. BRACKETT. The trenches are ordinarily from seven and one half to eight feet in depth, but for many reasons this depth is varied, in many cases. The depth of three feet to the top of the pipe allows the 48-inch pipes to pass under the gas service pipes, and is as near the surface as we can bring them, and keep under the gas service pipes. In some cases the 48-inch pipes are laid up within eighteen

inches of the surface of the street. That we are obliged to do to get over sewers. Then, in other cases, even for considerable distances, it is a question of either carrying the pipes down deep enough so that the top of a 48-inch pipe is below all house sewer connections, or of building a second sewer in the streets to take care of the sewage from one side of the street; and I am now considering the advisability of laying a considerable length of 48-inch pipes with the tops from eight to nine feet below the street surface for that reason. These are the conditions that govern the depth to which our pipes are laid. I do not think that it follows because pipes can be laid exposed for one or two hundred feet on a bridge without freezing, that a pipe line ten miles in length on the surface of the ground would not freeze.

Mr. Gilbert. I would like to say a word in regard to the shape of the pipe, whether it is to be perfectly smooth on the inside or not. Now, I do not know why it should not work in large pipes, the same as in small pipes. A pipe that has fittings at all the joints and elbows will corrode much quicker than where the pipe is smooth without any fittings; and I think that pipes will corrode faster where there are obstructions of that kind than where they have a free, smooth run right through. In the case of shut-offs on service pipes many of our water-works men use shut-offs that do not have a free, round, smooth hole through them. Many of these cheap shut-offs are made with a sort of oblong hole and are not smooth when they are finished. My experience has been that the smoother the pipes are, and the less obstruction there is, the less the pipes corrode.

Mr. Evans. In regard to the question the gentleman has just brought up respecting the house service taps, there is a corrosion which always collects, and I always supposed that that was caused by galvanic action between the two metals more than by the obstruction in the pipe.

Mr. Gilbert. I would like to ask the gentleman if he has not noticed the same thing where the pipe was jointed and also had elbows?

Mr. Evans. I know elbows fill up frequently, but these were cast iron, and perhaps uncoated.

The President. I would like to ask any gentleman here who has watched the action of water on pipes, whether, where there is no flow at the faucet, that is, no current, the corrosion is greater than where there is a flow?

Mr. Cook. In my experience no service has corroded so much as where the water has been turned on. There seems to be a galvanic action where the water is turned on. If the cock projects beyond the diameter of the pipe, I think there is not so much corrosion as when flush with the inside of the pipe.

Mr. Brackett. I think there is one reason that has not been mentioned why a pipe not in use will not fill with rust as quickly as one through which water is being drawn. A pipe in use is subject to a constant change of water and to a fresh supply of oxygen carried by the water, while the pipe that is not in use contains water from which the oxygen has been taken up by the rusting of the iron. As soon as the oxygen in the water is gone there will be no further rusting until a fresh supply of oxygen is available, and it is the practice in the use of sprinkling systems to avoid changing the water in the systems, so as to prevent the rusting; and it is also a fact that in green-house heating systems, where the same water is used over and over again, the pipes do not rust to any great extent. I think you will find that the branch pipes leading to hydrants are tuberculated less than the supply pipes where there is a constant flow of water.

In regard to the rusting of wrought-iron service pipes at connections; where coated pipes are used this would be accounted for by the fact that the coating is more likely to be broken at these points, and that where cut pipes are used an exposed end of iron is not covered by coating, and at the connections there will be a collection of rust. Of course, any obstruction would tend to collect any sediment that was passing through the pipe, and the collection of rust is more likely to be found at the junctions than on the smooth portions of the pipe.

PUMPING ENGINES.

BY ARTHUR J. L. LORETZ, M. E.

[*Read Dec.* 9. 1896.]

The subject of pumping engines, on which I shall speak to you to-day, dates back two centuries, and the limited time to-day only allows a rapid glance at the subject. A slight reference will be made to some of the principal machines for the purpose of showing you how little progress in the fundamental principles has been made during two hundred years in the economical handling of water.

If the noted constructors of those days had had the facilities of the present date, as regards tools and materials, at their disposal, I feel confident that there would be little left for the constructor of to-day to show as his progress beyond his predecessors.

After studying the examples of Bélidor, Héron De Villefosse, and others, as published in their works on hydraulics, written over two centuries ago, and later following the work of the illustrious Watt, in his almost exhaustive treatment of steam and its appliances, one cannot help but feel somewhat humbled that so little progress has since been made in machinery so universally in use and of such vital importance.

The hydraulic engines of Bélidor are certainly as perfect in their principles of pump mechanism as those of the most recent build, and one even gets suggestions from the descriptions and illustrations in his work entitled "Architecture Hydraulique" well worth the study of our present engineers.

The "Machines a colonne d'eau," described and illustrated in Héron De Villefosse's works, leave little for us to improve on as regards the direct acting pumping engine and the double acting piston pump mechanism which we still find our pump builders of to-day using. True, these were pumping engines operated by water pressure, but I found all the principles embodied in these machines that are used in the single direct acting and duplex steam pumps of to-day.

Some twenty-five years ago, I was much amused by the effort of a monopoly of direct acting steam pump makers to enjoin others from

constructing direct acting steam pumps, which had been put upon the market. I then gave the matter a thorough study, and after carefully studying some of our old masters saw how perfectly preposterous and worthless the claims were of these monopolists.

When one considers the grand and glorious workings of the monster compound pumping engines found in Holland, which were built nearly three quarters of a century ago, it is with a feeling akin to shame to the profession that I stand here without being able to point out to you examples emanating from up-to-date equipped establishments, which compare favorably with those masterful works. The little progress which has been made in this art speaks volumes for the skill of our early engineers, and it is very humiliating to us of to-day. It seems as though we were most closely limited in our surroundings, and that we revolve in the same circle and tediously repeat ourselves after a short period. Is it possible that the great old masters have reached the point of perfection, or have we less knowledge and boldness than our predecessors?

A partial answer to the above query may be found in the fact that the manufacturers of pumping engines have been, and are, unfortunately for the progress of the art, corporate monopolies, whose influence has been, and is, used to suppress innovations which might cause changes in the types of work in which they deal.

During these thirty years of untiring activity in this profession, I have often found myself alone in advocating the superiority of the fly-wheel pumping engine, knowing that this type was the one destined to meet the wants of the people, as simple, durable, and reliable machines.

From these principles I have never swerved, and can point to-day with consistency to examples of twenty-five years' constant and efficient work of the crank and fly-wheel vertical pumping engine, although I do not know where to find an example of a modern type of direct acting pumping engine that compares favorably in durability and efficiency to the old Holland engines.

With the knowledge of the state of the art in the past, let us now consider the necessary steps to be taken to construct a pumping engine that shall mark an advance step, bearing in mind continually that simplicity and durability of mechanisms, combined with efficiency, least first cost, and maintenance, are the all important factors in this problem. No matter how perfect and efficient a machine may

be, if its first cost and maintenance reach that point where its efficiency does not offer an inducement to the capitalist to make a profitable investment, the machine is a failure, and becomes but a mechanical toy, or useful only as an experimental apparatus.

The perfect steam pumping engine may be considered as an apparatus composed of two separate elements; one, the motive part, which consists of the motor or power generator (boiler and engine), and the other, the pump itself. The first should consist of a perfect steam engine plant, constructed so as to convert the heat produced by the coal into power, with the least possible waste.

Since, as a general rule, the load of resistance to motive power in pumping engines is almost constant, the problem of consumption of steam with its expansive powers, with regard to its most economical utilization for motive power, is easily solved.

Now, what may be considered the best and most available steam motor, the form that offers the least frictional resistance, is the vertical rotative type of engine, arranged with compound tandem or cross-compound cylinders, or in other words, a perfect high pressure and a perfect low pressure engine combined; also proportioned to work against the resisting force so as to expand the steam from twenty to twenty-five times its original volume at 80 to 90 pounds boiler pressure, and working at a piston speed of from 400 to 600 feet per minute. By quick piston speed we reduce the condensation of steam to a minimum in shortening the period of time which exists from the moment the steam leaves the generator until it performs its work in the cylinders.

It will be well to note right here that the high and low pressure cylinders are to be treated as two separate and distinct engines; the steam from the boiler or generator to be used for effective work on the piston of the high pressure cylinders only, live steam for re-heating purposes to be ignored entirely, either for jacketing or re-heating purposes.

Instead of steam jacketing, a thorough insulation of the entire cylinders and chests is to be made by a heavy and well constructed covering of asbestos to prevent radiation of heat, and which is sufficient to guard against condensation of steam, and also maintain the regular working average temperature in the steam cylinders. The use of live steam from the boiler for re-heating the steam, in coils, while on its passage from the high to the low pressure cylinder,

should also be dispensed with as wasteful in the extreme. Steam at ninety pounds pressure would only have an imparting temperature of 330 degrees, and its quantity is limited to the radiating surface of the coils, while its heat is taken direct from the coal consumed on the grate.

I would suggest that the boiler be invariably located in close proximity to the steam cylinders of the engine, and the exhaust steam from the high pressure cylinder carried through re-heating tubes constructed in the back connection of the boiler where the waste gases pass off to stack, at a temperature of from four hundred to five hundred degeees. From these tubes, or re-heater, the low pressure cylinder is supplied with its steam as from a secondary boiler, whose steaming surfaces are exposed to an average temperature of 475 degrees, with a heating capacity equal to the entire flue area of the boiler, while with the live steam coil the imparting temperature is but 330 degrees with a radiating capacity equal only to the radiating surface of the coil. By this means a higher temperature is obtained from the re-heater, and water in entrainment is re-evaporated. In a similar way the feed water for the boilers should be treated while being pumped from the hot well to the boiler through a similar heating contrivance without robbing the boiler of any heat.

I have found this plan to work admirably, and the initial steam pressure of the low pressure cylinder has been raised exactly to that of the terminal of the high pressure cylinder, an end I had been unable to accomplish by moderate sized steam coils.

The re-heating device should be located in a flue chamber between boiler and stack, provided with by-pass dampers arranged to carry the escaping gases direct to chimney, when the engine is stopped and no circulation of steam exists in the re-heating tubes, in order to prevent them from burning out, and to admit of their examination while the boiler is in action. The feed water heater should be placed in the same chamber as the re-heater, but located in such a manner as to receive the heat of the escaping gases only after they have passed the tubes of re-heater, in order that the latter may receive the highest temperature. In all cases I would suggest the use of brass tubes for re-heaters and feed water heaters.

With a first-class steam generator, a compound engine capable of expanding steam to twenty-five times the volume of steam admitted in the high pressure cyclinder and direct from a boiler in close prox-

imity to the steam cylinders; and the additional device for re-heating steam and increasing temperature of feed water, as above mentioned, by waste gases from the boiler furnace, it appears to me that the problem of producing the greatest mechanical effect through the medium of steam by the consumption of a given quantity of fuel, is practically solved without much difficulty.

After the production of motive power by the use of the perfect compound steam engine for a pumping engine, the next step to be considered is the pump or resisting force. This force consists in the exertion of moving a mass of water from a given point to a certain distance or to a given height. To perform this work economically it follows that this resisting force should be reduced to a mechanical operation, requiring the minimum of exertion outside of the actual static lift of the water and the friction of the water in the various pipe connections.

Water may be considered as a mass of weighty matter set in motion by the motor while driven and moved about in the pump mechanism to its final point of delivery, and like all bodies, after the first application of force to give it a regular and continuous momentum, requires but a constant and steady application of force to overcome the regular resistance due to static head and frictional resistance, much as the power of a locomotive is applied to the hauling of a loaded train of cars up a regular and uniform incline.

It therefore follows, that in a perfect pump mechanism, the moving mass of water should never be brought to rest after being set in motion in a certain direction, and especially should it never be reversed in its course, for whatever power is required by the motor in the exertion of starting a body of water in motion in one direction, twice that amount will be required and wasted in reversing its motion. If the water is allowed to come to rest only, the exertion to bring it from its state of rest to its maximum velocity will have to be renewed and the power wasted at each operation.

From the above it will be readily understood why steam and air-cushions, springs and other mechanical devices, are used for reducing the force of impact of surfaces in some pumping engines, and other power-destroying appliances interposed to preserve the mechanical parts from sudden destructive effects due to reactionary forces of the moving mass of water on the pump mechanism.

The effect of springs on water valves is as wasteful in motive

power as a reduction of valve openings, requiring a greater power on the pump piston to overcome the back pressure of such valves. In a perfect pump mechanism the valves should be but little heavier than the water, and provided with smooth, clear bored water passage of non-corrosive metal, and offer no flat contact surfaces to the water passage when opened. They should be free from complication, and of such a form as to be easily and quickly acted upon by the pump current. Where larger metal valves have been used, I have invariably applied springs to counteract their weight, with success. Some twenty-six years ago, while experimenting with a fifty-inch diameter pump at the Brooklyn Water Works, I removed the springs on large brass disc valves faced with rubber, which I had been urged to put on by the inspecting engineer in order to make them close promptly, although the weight of each valve alone amounted to some forty pounds. After removing these springs I found by the indicator diagram fifteen hundred pounds less exertion on the pump piston at each stroke.

In practice I have adopted a five-inch rubber ball valve, confined in a cage and working on a finished brass seat. With the opening bored out three and three eighths inches diameter, they worked admirably at a pump pressure of one hundred pounds per square inch. In lighter pressures this opening may be increased to three and five eighths inches, but the quality of rubber in these balls must invariably be of the best, as a poor quality will split. Only sufficient composition must be added to the rubber to give it a moderate hardness. They must also be very elastic.

I have many years ago experimented with pump valves, the openings and closures of which were either entirely or partially controlled by steam pistons, springs or power derived through mechanisms operated by the motive engine, but found that there always existed a clashing of forces between the pump current itself and the interposed mechanical force, which resulted either in a waste of power, or loss of action in pumps.

If the force of the current during its passage through the valve openings is interfered with, there invariably results a loss of action or of power. Water valves should be constructed so as to offer the least possible resistance to the passing current, and made to yield to it as gently in their resistance of opening and closing as a floating substance upon its surface. When I speak of pump current I mean

the motion of water in the various pump chambers preparatory to its delivery to the force main.

Bélidor recognized the importance of a nearly balanced valve and free water passage, for in his "Machine Hydraulique" he constructed a butterfly water valve almost balanced, making the swinging axis of the disc only sufficiently eccentric to make one side only enough larger than the other so that it would be acted upon by the current for its opening and closure, the valve when open presenting its minimum area to the current. This was certainly a very clever device to reduce the acting area to a minimum and increase the water passage area to a maximum with a free and straight passage for the current. In fact, there are few pumps of to-day that embody such a careful study of the subject as those noble old machines of over two centuries ago.

The next step will be the consideration of the manner in which the motive power is applied to the water for the purpose of raising it from its source or state of rest to the point of delivery at the required elevation. In a perfect pump mechanism the current should not be moved by a series of spasmodic shocks produced by a reciprocating piston or plunger, but after once being started should be kept moving as regularly in the pump mechanism as in the force or delivery main.

Were we to view through a sight glass the starting, then stopping, and continual reversing of currents in the pump chambers and cylinders of the reciprocating pumps of to-day, which are no different in their churning action from those of two hundred years ago, we could easily understand why some engines are brought to a perfect state of rest at each consecutive stroke by means of steam or air cushions, springs or other mechanical power, destroying devices to soften the violent reactions of the water which desires to keep up its forward and continuous course, and is prevented by the imperfect mechanism. The pump mechanism or lifting force should never be applied to the water in an opposite direction from that in which it is moving, but should be designed to keep up its motion in the same direction continually. A pump bucket or plunger should therefore never perform its lifting or forcing function except while moving in the same direction as the current, and should remain neutral or glide through the current with the least possible resisting surface, while preparing itself for the next stroke.

In a true and perfect pump mechanism there should never be less than four buckets or plungers, one of which is travelling at the rate of two or three hundred feet per minute, and the others preparing themselves to return and catch up gradually, in turn to the fourth before its speed is diminished for the return stroke. These motions can be very easily obtained from a double crank or flywheel engine, either by direct connections or through beams.

I would suggest that the pump speed be limited from two hundred to three hundred feet per minute as the most economical. I found by experience that although a well constructed pump can be operated almost noiselessly at a greater speed, yet the friction of the water against the contact surfaces increases to such a degree as to reduce the economy to a considerable extent.

Having advocated a steam piston speed from 400 to 600 feet per minute, and just now a water speed of 200 to 300 feet, we will now see how to combine two elements so different. Practically the beam rotative engine is the easiest solution of the problem, as the beam between its main and end centres affords every desirable speed from maximum to minimum. Thus, if we connect the steam cylinders to the extreme of one end of the beam, the crank and flywheel to the opposite, and the pumps on each side of main centre, half way between it and the ends, we will obtain a speed of 600 feet on the steam pistons, and 300 feet on the pump buckets or plungers, and while the bucket or plunger at one end is carrying with it the current, the opposite bucket is returning, gliding gently through the current to prepare itself to take up and continue the impelling force on the next stroke.

As air pumps invariably require a slow speed we can connect them at a quarter or third of the distance, between the main and end centre nearest the former, thus giving them either a speed of 200 or 150 feet, or less if desired.

In conclusion, I consider that the lifting process is far preferable to forcing, as in the former the driving mechanism moves with the current. Hollow plungers work admirably and are to be recommended, the only disadvantage or objection being the large packing surface.

In concluding this rapid survey of the subject, much of the solid material has been left without giving it its rightful importance, such as the steam generator, mechanical details, etc.

DISCUSSION (by F. W. Dean).

An examination of this paper reveals a great misconception of the action of steam and the trend and *rationale* of modern steam engine practice. The misstatements and exaggeration will tend to do great harm and retard the growth of correct ideas and the installation of better and better pumping engines if they are not met with vigorous and positive denials.

The author of the paper cannot be denied the privilege of worshipping the practice of two hundred years ago; but when he finds nothing to admire in present practice outside of his own creations, he cannot escape censure. He sees nothing to approve in the increased speed of pumping engines, in the use of high steam pressures, and in the perfecting of means of the utilization of the latter. He sees nothing in the extension of multiple expansion beyond two stages, nor in any steam pressure beyond ninety pounds per square inch, which by some occult power have been revealed to him as magic numbers.

The paper is considerably devoted to a discussion of the importance of handling water without deflections or reversals of the directions of currents. It is well to keep these matters in view, but the paper is full of exaggeration of the shortcomings of ordinary practice. The waste of power by interference with straight water currents is represented to be enormous, but when we remember that the efficiency of a pumping engine is from ninety to ninety-five per cent, and that our knowlege of stationary engines shows this to be chiefly made up of engine friction, it is evident that little more need be or can be done to perfect the water end of pumping engines. The "enormous" loss due to reversing water currents is referred to, but this loss is next to nothing on either the suction or discharge side of a pump if suction and discharge air chambers are used. With these provisions the work given up by the water (except a very slight amount of heat generated) is absorbed by the air which becomes compressed and immediately by expanding gives it back again to the water.

Steam jackets are condemned as being useless and wasteful, but too many proofs of their efficiency are at hand to accept such a view. It is sometimes objected by the uninformed that jackets condense steam, when this is just what they ought to do and must do to be of any value. Jackets are for the purpose of supplying heat to the working steam inside of the cylinder, to diminish its initial condensa-

tion, and condensation during expansion. The more the jacket condenses, the more it is performing its function, and great jacket condensation should be welcomed. Professor Thurston has shown that jackets in general save five times as much steam as is condensed in them.

The same argument applies to re-heaters, the difference being that the effect is produced on the working steam after it has left the preceding cylinder. Steam comes from the cylinder in a wet condition, the live steam in the re-heaters, by rapid condensation, gives up heat and dries and super-heats it so that it is in fit condition to do economical work in the next cylinder.

Members may remember the remarkably economical performance of the Louisville (Ky.) pumping engine. In this engine the jackets and re-heater condensed about seventeen per cent of the total steam used. While this is the greatest amount of such condensation on record, the engine is the most economical compound engine on record.

Concerning higher steam pressures than ninety pounds per square inch, it is probably enough to state that the compound engine has reached a degree of economy unanticipated a dozen years ago, and that this has kept pace with a gradual increase of pressures, and that these pressures have long since been beyond the ninety pounds mark.

DISCUSSION (by Asa M. Mattice).

While agreeing with the author that, in general, the rotative type of engine is the only one which should be seriously considered for water works use, I must take exception with him on a number of points.

First, the steam pressure which he advocates, viz., eighty to ninety pounds, can hardly be considered modern. The practice of the day has so conclusively proven the advantage of pressures more than double those mentioned, that comment on this point seems hardly necessary.

Then, his substitution of a non-conducting covering of asbestos, *instead of the steam jacket*, can only arise from a complete misunderstanding of the functions of the latter. One might as well say, that the possession of an overcoat supersedes the necessity for food. If the function of the steam jacket were *the prevention of radiation*, then the use of the steam jacket would be foolish in the extreme, for the steam jacket not only gives a greater radiating surface than the

unjacketed cylinder, but it offers a surface which is much hotter than the average temperature of the cylinder. The non-conductor is as essential in the one case as in the other, but all the non-conducting material in the world, if put on to one cylinder, would not *transmit heat to the expanding steam* as the steam jacket does. So much has been written on the theory of the steam jacket that a dissertation on the thermo-dynamics of the subject would be but idle repetition. What users of steam engines need to know is the practical result. A great many results of tests with and without steam jackets have been published from time to time, but the reports are so widely scattered throughout various technical journals, that they are not readily available to the average steam user. But so much of this literature has been collected in one little book, that I must call attention of our members to "*The Steam Jacket*" by Wm. Fletcher (Whittaker & Co., London, 1895). There is hardly a word of theory in the whole book; but the auther gives numerous examples from practice, relative to the use and abuse of the steam jacket, details of various tests, etc. He gives in tabular form the results of no less than sixty-one tests which have shown high economical gains from the use of the steam jacket, on the authority of such experts as Donkin, Emery, Unwin, Farcot, Hirn, Mair-Rumley and others. He gives examples, from actual practice, showing some of the defective jackets which have been from time to time cited as showing their uselessness. Some of these show nearly as great a misconception of the function of the steam jacket, as that in the paper under discussion. The book mentioned, which costs about two dollars and a half, should be in the hands of every water board about to invest in an engine.

The author's denunciation of re-heating by live steam may be classed in the same category with his lack of appreciation of the steam jacket, for the principles involved are practically identical, and the pudding has been abundantly proven by the eating. Re-heating by flue gases, as advocated by the author, has often been tried with good results as to duty, but the apparatus has generally been costly in the matter of repairs. There is one thing that can be said of live-steam jackets and re-heaters, when properly made, which cannot be said of many parts of an engine, and that is that they pay large returns on the investment without appreciable cost for repairs, and with next to no attention.

The author states that in a perfect pump mechanism the moving mass of water should never be brought to a state of rest after being once set in motion. I do not believe that there is any other matter connected with pumping-engine designs on which so much time has been wasted by inventors as this. The number of inventions said to produce the desired result rivals that of inventions for producing perpetual motion. The fact is too often lost sight of that in a reciprocating pump, whether direct acting, or of the flywheel type, the piston or plunger *must come to a dead stop* at each end of the stroke, and that, in order that the suction valves may close, the water, too, *must* come to a stop. And after once coming to a stop it does not matter whether it be set in motion in the same or the opposite direction. It is beyond the power of the designer to do more than bring the water to a state of rest and start it again with as little shock as possible, and to keep down the velocity of the water in the pump chambers, regardless of the velocity of the plunger.

The loading of pump valves by weights or springs, decried by the author, is an evil which should be eliminated from pumping engine design if possible. But it is a question of a choice between several evils. First, to increase the pump resistance by these weights or springs; second, to close the valves by independent mechanism; or, third, to eliminate the weights, springs, or mechanism, and incur a greater loss by slip. It is better to lose, say, two per cent by spring loaded valves, than to lose four per cent in additional slip, due to sluggish closing of the valves. I do not see how the ball valves advocated by the author can possibly solve the difficulty. Unfortunately, the matter of weirs, Venturi tubes, or discharge cones, for measuring the output of pumping engines, does not receive the attention from water works managers that it should, and it is, therefore, impossible in most cases to say what proportion of the dollars is lost in excessive slip. If we could place two engines side by side, one with loaded and one with unloaded valves, the relative plunger displacements of the two engines, working on alternate days or months, would give some information on the subject, even without accurate measuring devices, although the latter would be preferable. It so happens that at Lynn, Mass., there is such a case, viz., one engine with heavy cast-iron valves and one with rubber ball valves. Sometimes one engine runs and sometimes the other. The reports of the Water Board show that in five years the iron-valve engine

ran 527 days and the ball-valve engine 1,051 days, which periods are sufficiently long to eliminate any ordinary errors. Taking the number of revolutions given by the reports, and the sizes of the plungers, it appears that the average daily plunger displacement of the ball-valve engine is more than nine per cent in excess of that of the iron-valve engine; from which it follows that the good people of Lynn must be nine per cent thirstier when their water is pumped through ball valves, or else that the unloaded ball valves give that much more slip. The latter appears to be the more likely. If we take the performances of the two engines for succeeding months we find a similar difference in slip, but the five-year average is a better proof. Of course, the loading of valves can be overdone, but it can be carried to a considerable excess without producing as great a loss as would be produced by slip with the unloaded valve.

The advisability of not less than four plungers, and the limitation of the plunger speed to 300 feet per minute, both advocated by the author, are not proven by practice. Take, for instance, the Calumet and Hecla Mining Company's engine "Ontario," with two plungers, 5 feet stroke, worked by a *single crank*, and running 38 revolutions per minute without shock. One of the easiest running pumping engines I have ever seen is the *single crank* engine of the Barmen Water Works at Volmarstein, Germany. I have seen this engine, of 43 inches stroke, run 63 revolutions per minute (a piston speed of 450 feet per minute) against 750 feet head, without perceptible shock.

The author very pertinently calls attention to the fact that high duty should not be attained at such a high first cost of engine, that the investment is not a profitable one to the capitalist. This question of high duty and first cost is one that is too often not properly considered by our water works officials. In this connection, I would call attention to the report of the Louisville Water Company, for the year 1895, to show the possibilities of the compound pumping engine. From this report, it appears that the duty of their engine for the entire year, using Pittsburgh coal (which is much inferior to our Eastern coals), and counting all coal used at the station, was 124,395,952 foot pounds per 100 pounds of coal. The report adds, "The coal was not housed; was exposed to the weather in out-door piles, from which it was taken, weighed and passed into the furnaces, wet or dry, and charged to the engine without deduction for

moisture, cinder, clinker, or ashes." I cannot find that this duty has ever been equalled, even by triple-expansion engines. And in this Louisville engine, by the way, are embodied nearly all of the features which the paper under discussion classifies as disadvantages; the cylinders are steam jacketed, there is a live-steam re-heater, there are but two plungers and one crank, and the valves are heavily loaded by springs.

But, to return to the question of first cost, I would like to call attention to the accompanying table, prepared by our late Secretary, Mr. R. C. P. Coggeshall, Superintendent of the New Bedford Water Works, to assist in the choice of a couple of new pumping engines. From this table may be found by inspection the relative prices which could be paid for engines of various duties in order to give the same return on the investment. The table gives the figures for various duties progressing by ten million foot pounds, but any intermediate figures may readily be found by interpolation. It will be seen that for an engine to pump ten million gallons daily at the same duty as the Louisville engine, or 124 million foot pounds, they could afford to pay $47,000 more than for an engine which would give only 100 millions duty. They now have at New Bedford a direct-acting engine with "high-duty" attachment, which has given a yearly duty of a little less than 86 million foot pounds, but let us call it in round numbers 90 millions. It will be seen directly from the table, that for an engine giving 120 millions duty they could afford to pay $67,250 more than for an engine of their direct-acting "high-duty" type giving 90 millions duty. As each of their new engines has been contracted for at a cost of less than $75,000, including engineering expenses, it follows that a direct-acting engine would have to be sold to them for about $7,750 in order to be a good investment, which is very considerably less than they would be likely to get a ten million gallon engine for! Let us compare, also, the cost of the high grade engine with one of the direct-acting compound type without high-duty attachments, such as are often used in water works on account of low first cost. There is no authentic record of any engine of this type having given a duty as high as 60 million foot pounds. But, supposing that duty to be obtainable, the table shows that $202,000 more could be paid for an engine of 120 millions duty than for one of 60 millions. In other words it would pay better to buy the more expensive engine *than to have the compound direct-*

TABLE showing annual cost of coal for pumping ten million gallons of water daily to a height of 170 ft. under different rates of duty, with coal at $3.75 per ton of 2,000 lbs. The table also gives sums the interest of which at 4% represents the saving effected by an engine of superior economy over an inferior one.

Select the column headed by the higher duty. Then select the line beginning with the lower duty. The sum found at the intersection of the column and line is that which, at 4% interest, could be paid for the higher duty engine above the price of the lower duty engine.

Lower duty, in million foot pounds per 100 pounds of coal.	Pounds of coal required to raise ten million gallons of water, 170 ft. in 24 hours.	Cost of coal for 365 days at $3.75 per 2,000 pounds.	HIGHER DUTY, IN MILLION FOOT POUNDS PER 100 POUNDS OF COAL.									
			150	140	130	120	110	100	90	80	70	60
50	28,360	$19,410	$323,500	$314,000	$298,750	$283,000	$264,750	$242,750	$215,750	$182,000	$138,750	$81,000
60	23,630	16,170	242,500	233,000	217,750	202,000	183,750	161,750	134,750	101,000	57,750	–
70	20,250	13,860	184,750	175,250	160,000	144,250	126,000	104,000	77,000	43,250	–	–
80	17,720	12,130	141,500	132,000	116,750	101,000	82,750	60,750	33,750	–	–	–
90	15,760	10,780	107,750	98,250	83,000	67,250	49,000	27,000	–	–	–	–
100	14,180	9,700	80,750	71,250	56,000	40,250	22,000	–	–	–	–	–
110	12,890	8,820	58,750	49,250	34,000	18,250	–	–	–	–	–	–
120	11,810	8,090	40,500	31,000	15,750	–	–	–	–	–	–	–
130	10,900	7,460	24,750	15,250	–	–	–	–	–	–	–	–
140	10,010	6,850	9,500	–	–	–	–	–	–	–	–	–
150	9,450	6,470	–	–	–	–	–	–	–	–	–	–

acting engine presented to them, with the addition of a bonus of about $125,000 thrown in. These figures are for ten million gallons daily capacity. For a smaller pumpage rate they would be correspondingly smaller.

If our water works authorities would look into the question of first cost as thoroughly as they did at New Bedford, we would see a good many dollars saved. It is a very easy matter to get up a table similar to Mr. Coggeshall's to suit any case, simply by substituting the pumping capacity, feet head to be pumped against, and cost of coal, according to local conditions.

Moreover, as a general thing, a part of the cost of high grade engines — I may say a large part of the cost — goes for high grade material and workmanship, which is offset by less cost of repairs, although these items of cost have nothing to do with the increase of duty. The old McAlpine engine at New Bedford is a fine example of this. Although built in 1869, it is now, *after twenty-seven years running*, their "old reliable," and with 30 pounds steam pressure it gives a duty only fifteen per cent less than their compound high duty engine built twenty years later and running at 110 pounds pressure.

In conclusion, I would refer to a side of the question which is too often neglected — the æsthetic side. In water works construction we find much money spent to please the eye. We find elaborate cut stone work about reservoirs, where very rough construction would suffice. We find elaborate gate houses, where shanties would afford all necessary protection. We find the grounds artistically laid out, with well-kept lawns and walks. We find the buildings at the pumping station of ornate architecture. But when we open the engine house door we find, too often, a veritable nightmare of engineering construction. Now, whether we have a high duty or a low duty engine, steam jackets or no steam jackets, valve springs or no valve springs, four plungers or one plunger, why not let the engine be in keeping with the other works, and spend a little money to make it as pleasing to the eye as the buildings and grounds?

DISCUSSION (by the Author).

After a perusal of Mr. Dean's discussion of my paper, I fail to find "vigorous and positive denials" of facts given. That the general principle of pump mechanism of over a century ago are the present day's practice stands still an undisputed fact.

The writer's experience of thirty-five years was thought to entitle him to present some suggestions to the members of the Association. Having outgrown the wisdom of youth, I desired to pay tribute where honor was due, namely, to the originators of the pumping engine.

I have advocated a steam piston speed of six hundred feet per minute and a water speed of three hundred feet, which shows my approval of increased speed in pumping engines, notwithstanding the two hundred feet limit of ordinary practice among direct acting pump builders.

The fact that the highest attainments in pumping engines can only be reached by a quick steam piston combined with a moderate water piston speed of three hundred feet per minute remains yet unanswered, as is also the handling of water against weighted valves explained according to my experiments on the Brooklyn engine some twenty-six years ago.

As to the benefit from higher steam pressures, he fails to explain why the old Holland and Cornish engines, built nearly sixty years ago, give such a magnificient efficiency. A single cylinder Cornish beam in the United mines developing an average duty, in 1842, of 114,361,700, with less than 20 pounds boiler pressure, while to-day, engines with 125 or even 200 pounds boiler pressure can hardly be compared with it in efficiency.

As to the subject of re-heating steam, but little light has been thrown on the subject of my suggestion, — that it may not be best to reheat the steam, while on its passage from high to low pressure cylinders, by live steam coils at extra fuel cost, rather than by waste gases escaping to the stack.

Mr. Mattice states in the second paragraph that comment on the point of very high steam pressure is unnecessary, and that a moderate pressure of 90 pounds is hardly modern, yet he concludes his discussion by stating with reference to a compound engine: "I cannot find that this duty has ever been equalled, even by triple-expansion engines." As this latter seems to contradict the assertion in his second paragraph, further comment is superfluous.

No one doubts the efficiency of steam jackets in the absence of other re-heating devices. From the moment steam leaves its generator to perform its function on the steam piston, it evolves heat, and the greater the pressure, the greater the capacity for throwing off heat derived from the coal pile. The natural conclusion would there-

fore follow, to reduce the distance of its travel and prevent, by artificial means, this evolving of heat called radiation. To perform this act by means of additional fuel, when large masses of gases at an average temperature of five hundred degrees are wasted up the stack, seems unpardonable.

Surely, no one will dispute the fact, that even steam jackets and coils are used to keep up the life of steam before final action, and that they in turn must be thoroughly protected by asbestos from evolving their heat, excepting into the walls of the steam cylinders. Now, if the heat evolved by jackets to working steam can be dispensed with, and a greater degree of heat imparted thereto by waste gases, why should such objection be raised to the device, especially when it can be performed at the saving of fuel?

The objection raised by Mr. Mattice that such an apparatus for heating steam by waste gases is costly in the matter of repairs, is no argument against the principle, it being then only a question of mechanical ability to apply the principle

There appears to be no prettier motion for the opening and closing of a valve than that imparted to it by the current of the water as the engine passes the dead centre of the crank, giving that gradual increase and decrease in lift coincident with the approach and departure of a circle from its tangent point.

Let us suppose that four buckets of the Cornish type were operating, one above the other, in one long vertical cylinder, and that each received its motion from the opposite ends of two beams of a duplex engine; there would always be one bucket raising the current in the upright pipe at the maximum piston speed, imparted by the circular motion of the crank between the second and third quarter motion of the semi-circular crank movement of the up or down stroke, as the case may be.

Now, it is evident that the four buckets which are actuated by four different movements of the rotative motion of the crank-shaft, are so raised with regard to each other that there will be one invariably moving in an upward direction at its greatest speed, while the other three are idlers, and preparing to catch up to the fourth, allowing their valves to open or close gradually during a period of one fourth of the entire revolution of the engine. This is what the author considers an ideal pump.

The Lynn engine may embody indirectly, to a certain extent, such a principle, yet is far from being an entire ball-valve pump, large

heavy metal valves being there in use. Nor is this criticism relative to the slip of the large Lynn pump considered fairly when compared with the smaller one; for, when the larger one is in operation, considerable water is used to operate a dynamo for incandescent lights about its surroundings. Yet, even then, when one considers that the cost of that engine was less than that of the smaller one with only one half of its capacity, allowances may be made for slip and duty.

The author does not and never has advocated too low-priced pumping engines, but is a strong believer in the happy medium. Simplicity, durability and efficiency, combined with a pleasing exterior, ought to be the aim of builders, while the first cost should not be too great.

For instance, a 10,000,000 gallon engine that costs $35,000 with an average duty of 110,000,000, is certainly cheaper than a 5,000,000 gallon engine at the same price, which develops a duty of 120,000,000.

Then again, all engineers know how perfect the management of all high duty plants must be, and that the best mechanics are needed to operate them and not the cheapest, which also involves quite an additional annual expense not taken into consideration in the discussion.

If a 20,000,000 engine can be built for $75,000 and develops a duty throughout the year of 120,000,000, and requires but ordinary attendance, such an engine is preferable to one that costs $175,000 and develops a duty throughout the year of 130,000,000 and requires extra help and special mechanical skilled attendance.

When an investment is made in a plant, the annual coal pile required to be supplied and the pay roll are the important factors to be considered, with the interest of the cost of the plant. A duty developed with hand-picked coal will hardly be a satisfactory test as to the quantity and quality of coal required during the year for a certain amount of water delivered into the reservoir for distribution.

THE PROTECTION OF SURFACE WATERS FROM POLLUTION.

BY PROF. W. T. SEDGWICK.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON.

[*Address, Dec.* 9, 1896.]

Within the last few years I have had occasion to investigate various outbreaks of typhoid fever, and in the course of these investigations, covering now some fifteen epidemics, it has been gradually more and more impressed upon me that too little watchfulness is exercised, in many cases, to prevent the pollution of surface waters. It is true that we have had, in Massachusetts, ever since 1878, an excellent law forbidding to a certain extent the pollution of rivers and other streams, and this law is well enforced. But I do not now refer so much to the more gross and obvious pollutions, as rather to a class of what I might call minor or temporary contaminations. These fall chiefly under two heads, namely: —

1. Pollutions due to permanent residents on the watershed.

2. Pollutions due to temporary residents, — such as laborers engaged in constructions, additions, or repairs, and to visitors, — such as fishermen, picnickers, and the like.

I will explain exactly what I mean by two illustrations of each class, — two drawn from my own experience and two from the experience of others.

One of the best examples of danger from the pollution of surface waters from regular residents on the watershed is the famous Plymouth, Penn., case. This is too familiar to need detailed statement, but briefly was as follows: —

The town of Plymouth, Penn., had a water supply obtained by damming up a stream, and on the upper part of that stream, above the reservoir, was a resident family, which for many years had been in good health. During a certain winter, however, — I believe it was 1885, — some members of the family fell ill with typhoid fever, and the excreta from the patients were thrown out on the snow on

the watershed. There they remained during the winter, but when the spring thaws came they were carried down into the reservoir, and in this town of some 8,000 inhabitants there occurred within a very short period about 1,200 cases of typhoid fever. Of course, the reservoir was a relatively small one, and the contamination was therefore very direct. But it was a case in point,— that is to say, it was the pollution, sudden, unexpected, unusual, from a family of permanent residents on the watershed, a pollution which was carried directly to the water supply and eventually to the consumers.

A similar case I was myself fortunate enough to witness, namely, that of Windsor, Vt., two or three years ago. This case was very similar to the Plymouth case, except that the cause was not quite so clear. Windsor, Vt., is a comparatively small town, and had dammed up a brook in a narrow gorge, and made a long, narrow, and not very capacious reservoir. On the upper end of it were a few houses, or rather on thes tream leading directly into it, and in one of these houses there was found a case of illness as to the nature of which the physicians disputed more or less ; but to the satisfaction of at least the health authorities of Vermont, better to their satisfaction than to my own, I must admit, it was claimed to be undoubtedly typhoid fever. Connected with this house was a common privy, which was flushed out by the melting snow, and the contents of which were carried down into the brook and from the brook directly into the reservoir. The reservoir being small, it was to be expected, as happened, that the people suffered immediately and very seriously. There was abundant evidence that the water was infected, and there was reason to believe that the original case was probably a case of typhoid fever, although the facts were not as clear as they were in the other case, or as clear as could have been wished. There was no doubt whatever that the typhoid fever came from the water supply, because facts like this, for instance, existed : Windsor is the seat of the State's prison, the prison being supplied with a different water, and there were no cases in the prison among the large number of prisoners. I think there was one case in the prison but it was the wife of the keeper or someone who had been out and about and had drunk water elsewhere in the town. The prisoners were wholly unaffected, while the people in the town, the ordinary water consumers, were very heavily stricken.

The epidemic of typhoid fever in Providence, R. I., in 1888, was

traced by the health officer, Dr. Chapin, to a similar origin to that in Plymouth, Penn., and there are many other examples on record.

It appears to be true, then, that while permanent human habitations on a watershed may for years do no damage whatsoever, they do, nevertheless, constitute a permanent menace to the purity of the waters collected in their vicinity. It is no sufficient answer to say, "We have had houses on our watersheds draining into our water supply for many years and have never had any trouble." That may be very true, but the reason may be merely that these particular families have never during that time happened to be infected with typhoid fever. The blow may yet fall at any moment.

We turn now, in the second place, to the other class of cases of pollution which we have to consider. And here I shall begin with the well-known Caterham case, giving thus first an example from foreign experience and then one from my own.

This Caterham case occurred in England, in the village of Caterham and Red Hill, in 1879; and it is particularly instructive, I think, for water works men, because it illustrates a source of danger which they are apt to forget. Caterham and Red Hill had been growing, and they wanted more water. In this case water was derived not from the surface, but from wells in the chalk, and the officials started in to make a new well to give them an additional supply. In the course of the digging of this well, the instructions were that any workman who had to defecate should either go up in the lift to the surface and use a privy there near the mouth of the new well, or else, in case he could not do this, should use a bucket below which was kept for that purpose, and which was occasionally hauled up and emptied. Things went on well enough for a while, but all of a sudden a very serious epidemic of typhoid broke out in Caterham, and to a less extent in Red Hill which got its water from the same source. A careful investigation showed there was pollution of the water supply, and still further investigation showed that at the time when the new well was just being completed, and connection between the old well and the new was about to be made, one of the workmen had had what turned out afterwards to be probably typhoid fever. That is to say, he had complained of feeling "run down," "played out," "dragging around," and had had diarrhœa and, no one watching him particularly to see that the rules were carried out, as he admitted afterwards, he had been in so much haste that he had n't even waited to

use the bucket, but had defecated right in the bottom of the well, and when he had used the bucket it had been generally full and running over at the top, so that as it was lifted up out of the well, it used to slop over more or less; and all through the investigation it was perfectly evident that things in that well were not as they should have been. Moreover, the date of this man's illness, which would answer for the seed, and of the crop of cases which appeared below among the water takers, corresponded. The cases appeared nowhere else, excepting in one rather amusing instance, where a family had been stealing water, having made connection surreptitiously with the company's pipes. There were a number of cases in this family, and at first it was very puzzling to the medical officers; but when they found out that a pipe had been connected without anyone knowing of it, and that the family had really been getting the same water as the other victims, it seemed that good, heroic justice had been done them.

That was in 1879, and, though upon a ground water supply, illustrates very well an important point in this matter, which is the care that needs to be taken in *repairing* or *adding to* an existing supply. There are, as I shall show, conservative features in these cases. If your reservoirs are large enough they may be seriously contaminated at one end, and yet safe to drink from at the other, as is the case in Burlington, Vt., where raw sewage is put into the lake at one point, while the water supply is drawn from another; and as is the case in many other of our lake cities, such as Buffalo, Cleveland, Chicago, Milwaukee, and Duluth. But, at the same time, it is not good practice to drink from one's own cesspool, and if one must drink from it, he must be careful to drink from the other side, and not from the same side into which he puts his sewage. But if he does not know that he has a cesspool, and supposes that he has a good surface water, still, in making additions to that supply, and having a lot of workmen about, he needs to be very careful. It often happens that the population employed in making additions or repairs to a water supply is as large as that of a small town, and no superintendent would feel comfortable if he knew that a small town were suddenly planted directly upon his watershed, where he had n't suspected its existence before. Yet the same superintendent sometimes forgets that in keeping large gangs of men there six months, or even three months, or even three weeks, he may get into very serious

trouble. This Caterham case was a good illustration of that, because it was traced directly to a workman so employed.

I may now give a similar case from my own experience, and affecting surface water. Several years ago, a new reservoir was under construction for a large and important American city. It was, when done, to be connected to an existing system of reservoirs, and during the work of stripping and dam-building, large gangs of men were employed. The stream which was to be dammed up, naturally ran through the valley where these men worked, and on into the lower reservoir. An epidemic of typhoid fever broke out among the workmen. I was called in to study the *cause* of this epidemic, but I very soon saw that interesting as that study was from a scientific point of view, the possible *effects* of the epidemic were practically far more important. I was sent there to find what the cause of the typhoid fever was, but this question had to wait while I tried to prevent the typhoid germs produced by the people who were working on this brook and using it as their drain, from reaching the consumers of the water after they had got into the reservoir below. So I abandoned very quickly my original hunt, and went after another and far more important kind of game. There were hundreds of men at work, and quite a number of them suffering with typhoid fever, all about or very near the brook. Many of them were visibly using it as a drain, and a defecating place, for they could be seen to retire into the bushes right on the shore of the brook; and among these men I knew a certain percentage had typhoid fever, while the brook was running directly into a reservoir to be used for drinking. Fortunately, the reservoirs were so arranged that this one could be disconnected for a time; earth closets were put in, disinfectants employed, and every possible precaution that we could devise was taken to prevent further trouble. I am happy to say that our efforts were entirely successful.

I believe that these cases are a good deal commoner than we know, and I believe it is a subject that a water works superintendent needs to keep constantly in view. As a rule, to be sure, he is not the man who has most to do with it. The work is put out to contractors, and the superintendent, perhaps, is busy around the town or city which he serves, looking after the piping, while laborers by the hundred it may be are at work on the watershed, perhaps polluting the water supply in a very serious way.

In this connection I want, also, to speak of the dangers from fish-

ermen, bathers, picnickers, boatmen, and summer cottagers. And first, as to fishermen. It is a fact, as you all know, if you have large reservoirs that contain good fish, that there is a great desire among certain people to fish on your reservoirs. There are two kinds of fishermen, those who go out in boats and those who fish from the shore. Now it often does not take a great deal of inspection of the shore of any reservoir which is also a good fishing pond to find evidence that it is used as a kind of privy. I have seen instances of that kind, one not very long ago, where within a comparatively few feet of a gate-house, I saw a considerable number of evidences of defilement of the shores, what might be called shore defecation. That comes, of course, mainly from people who go out for a day's sport, as they call it. They are not always careful to empty their intestines before they leave home, and even if they are nature may make another call, and then they are not at all particular to go off the watershed. Of course, the majority of these people are healthy, and what they leave is simply filth. But among them, now and then, if you take a large percentage of people, there are sure to be some persons in the early stages or having mild cases of typhoid fever, and if Asiatic cholera were to visit our country there might be some affected with it among such people. I grant that the danger is not very great, but it is one of the things to be afraid of, one of what I have called the minor dangers. None the less I believe it to be a real one, and I have myself seen abundant evidence that it exists in fact and not merely in theory. Anyone who will take pains to look and will inquire into the class of people who produce the deposits, will very soon satisfy himself that in some cases, at any rate, these involve grave dangers.

Then there are the fishermen who go out in boats and do not stick to the shores. Their boats are very often of the heavy, broad-edged type, and fishing often lasts through the night. It is not at all uncommon for men to fish all night after eels, for example. I know what I am speaking about on this matter, because I have actually looked into it; this is not theory, it is fact. Men do often stay out over night on ponds, and sometimes on reservoirs. And when they do, it is not at all unlikely that they sometimes make use of the edge of the boat as a convenient seat, and contaminate the water. Now if it happens that just at that time the boat is over the upturned end of the in-take pipe, and if it further happens that the fisherman is in

the early stages of typhoid fever, — these I admit are remote possibilities, nevertheless they are possibilities which ought to be guarded against by any one who is looking out for everything, — then there is here opportunity for contamination. In my judgment no water supply should be used as a fish-pond or for purposes of entertainment. That is not what it is made for. It is intended to provide good water to put inside the alimentary canal, and it must not be allowed to serve as a convenient place into which to empty the alimentary canal.

Next, there are picnickers. Nothing is more attractive for picnics than the shore of a well-kept reservoir, but if you will investigate picnic places you will find that privies are not always present, and that the bushes near the shore are resorted to a good deal. If there are privies there they are often in such a position that they can be flushed out by the rains and emptied from beneath more or less directly into the lake or pond. That has happened more than once in this State and is still happening. Then, of course, among the picnickers are fishermen who use the shore or use boats. There are also those who go simply for the boating or sailing, though they perhaps do not generally stay as long. A new and pressing sanitary problem is coming up in connection with the picnicking encouraged by the electric and suburban railways which are establishing at convenient points "grounds," "parks," "casinos," etc., in order to increase the number of their passengers. In some cases these are very large establishments, and in all cases they are used by a varied and ever-shifting population. On no account should such establishments be allowed to fix themselves on the shores of lakes or reservoirs used for public water supplies, since the general character of a picnicking population is such as almost to make certain more or less shore defilement, boating, fishing, bathing, and the like, to say nothing of the problems of sewerage entailed by such aggregations. A picnic ground with an average attendance of one thousand a day may be, for various reasons, more objectionable than a fixed town of equal population at the same point.

Then there are the summer cottagers. They always like to put their houses right on the shore of a beautiful lake, which perhaps is used as a water supply, and if they do, their drainage must be got rid of somewhere. Of course it does not often go directly into the water; it may or may not go indirectly. That is a thing to be looked after.

And the matter of bathing. Of course, nothing is more tempting than a plunge into a cool, clear lake on a hot summer day. But the time when we bathe most, along in August for instance, is just the time, also, when typhoid fever is most common among our people, — not when the deaths are most numerous, but when the cases are beginning. And these early cases, before people know that they have the disease, walking or other mild cases and so on, are such as are liable to lead people to take a day off. There is nothing commoner, when inquiring into the history of a person who is down with typhoid, than to find that he left his business at first and went off for two or three days to rest, thinking he was a little "run down" or "played out," and that if he could only get a little rest he would be all right. At such times he is very apt to resort to a lake or some similar place, to rest on the shore or to rest in a boat out on the lake; and in the course of that resting if his diarrhœa happens to come on, he being about to come down with typhoid fever, as may very easily happen, of course there is danger. I am allowing that these are minor dangers; I am not pretending that they are as grave as those from drinking from a highly polluted river; but these are things that are to be looked after; and it seems to me that an Association like this, that is well aware of the more serious dangers, ought also, in New England where we hope to have the best of all these things, to have its eyes open for the little dangers as well.

But you will naturally ask, Why, if these things are so, have n't we had more trouble than we have had? The answer is, that all such contaminations are small in quantity; that the opportunity for dilution, sedimentation, purification by light, and so on, is great; as witness, Chicago, and Burlington, Vt., and the other places I have mentioned. Yet we probably have had trouble and have not known it. I have reason to think that I have seen one or more instances of the kind, where, for example, there was a mild epidemic of typhoid in a city, and where, after examining carefully into the milk supply, and into the ice supply, and into everything that anyone could think of, I have finally discovered that the fever spread out from the mains of the water works. When I came to plot the cases these pointed towards the water works. On looking at the reservoir I could not, at the moment, find anything, but I did find that the shore had been used as a sort of amateur privy, and that numerous boats were drawn up on the shore and lay there all ready for anybody to

get into and go out fishing, it might be right over the in-take. I say I have seen cases of that kind, and in one case I was led to attribute the trouble directly to that source.

The whole problem turns, of course, on the life of disease germs in water. And here we are very much in the dark. It is a very reassuring thing to open a book and read that Professor Blank or somebody else has experimented and found that typhoid germs will live only twenty days, or sixteen days, or two months, or something of that sort, in water. The only trouble is that if you open books enough you will find that no two people agree about it. Some will say they will live a few weeks and no longer; others have found that they will live for months. Some have found that they will live in ice; some have found that they die in ice. The only safe ground to take at present is that we don't know very much about it. We know that in laboratories, in glass dishes and so on, under certain special conditions, certain good men have got certain results. These results are valuable, but they do not enable us at present to say with absolute certainty that if we know that typhoid germs went into a certain reservoir on a certain day, three weeks or six weeks from that day we can drink the water with impunity. We don't know that at all. We know very well that most things keep better on ice than they do in the open air. It is possible that the very coldness of a winter night, for example, preserves the life of these things. Cold does not kill protoplasm as heat kills it or as boiling kills it, and the only safe ground for us to take at present in regard to the life of these germs in water is that we don't know much, if anything, about it. That is the ground I have taken and I believe it is the only safe ground. We are making experiments, and various observers are making experiments, and in time we shall know more. But at present the safest way is to keep germs out of drinking waters; but if they get in, to give just as much time as possible before the water is used, and if the time is short to issue a warning. If it is not very short it may be a fine point to decide whether it is necessary to issue a warning or not. That is a thing nobody but an expert can tell, and he must know the local conditions and be familiar with what has gone on in other cities, such as Burlington, Vt., Chicago, and so on.

The gist of all this is, then, that the ideal watershed would be one without any human being on it,— without any *human* being. We do not believe that the birds that fly over drop in typhoid germs. But

what we do know is that trouble has come in certain cases from human beings. We know also that human beings are essentially dirty, especially those of the lower orders. And we know further that when people are a little sick, in the early stages of various diseases, they are apt to take vacations, and go and camp out on a lake or something of that kind, perhaps feeling not sick enough to go to a hospital, or because they don't want to work. So that putting all these things together, from what I have actually seen in the last few years, I have felt that there was a point here. That aside from the gross pollutions which everybody here has learned by this time to guard against, there are these smaller points, these minutiæ, to be looked after; and that the presence, temporary or permanent, transient or constant, of any considerable number of human beings on a watershed, or even of a small number of human beings on a watershed in such a position that their excreta can in any way reach a surface water, is in itself matter for grave anxiety and concern. It may not lead to any trouble whatsoever. If the pond or lake is large and well aerated and well lighted, and the consumption of water is small in proportion to the volume; if the point of possible contamination is very remote from the outlet, etc., it may very likely happen that no trouble whatever will come. But, on the other hand, if it is merely some little brook dammed up in such a way that rapid consumption or a sudden change from one supply to another might draw it down rapidly, then it is a matter of very grave concern if that supply becomes contaminated.

I have seen, for instance, within a few months, such a small supply as I speak of made by simply damming up a little mountain brook, forming a little reservoir only eight or ten feet deep, and hardly bigger than this room, and on the bank of that reservoir a house so placed that the roof-water must about necessarily, in time of heavy rains, flush out the privy and wash the contents directly into this little pond only a few feet away. Now such a condition of affairs, while it looks well enough, a pretty house, pleasant people there, beautiful country, and all that, such a condition is not allowable in the present state of sanitary science, because there is a possibility there that something shall be washed into the water supply, and if so washed in, the reservoir being small, the consumption must be quick, especially if the supply should be heavily drawn upon by a fire or anything of that kind, and the result would be that the contami-

nation would get, while very fresh, to the consumers. That is the one thing to dread, that the germs shall pass quickly from one intestine to another. If they are long on the way they generally die out, we believe, or at least disappear in some way. But any means whatsoever by which they can move quickly from one intestine to another is fraught with danger to the second intestine.

I want to repeat that I do not wish to be understood as claiming that every water supply in New England is in danger because there is a farm house on the watershed. I only mean, that if there is a farm house, even one farm house, on the watershed, that fact ought to be known by the superintendent; and he ought to know whether there is a little rill running down from the back door, and leading off into his water supply. I want especially also to emphasize the fact that the presence of laborers in repairing or extending a water supply constitutes a pretty serious danger, more serious, probably, then the one I have just mentioned of the existence of houses on the watershed.

Discussion.

Mr. Hazen. The watersheds feeding our reservoirs are often used as cow pastures, and cows wander around the ponds, and leave their droppings in various places. I would like to know if Professor Sedgwick has ever made any study of this question, and whether he ever knew of typhoid fever, or other diseases, being caused by the droppings of cows or other animals?

Prof. Sedgwick. I have not, Mr. President. In the present state of our knowledge and belief, the present state of our ignorance I ought perhaps to say, we do not believe that typhoid germs can come from the lower animals. There are some diseases which we believe may come from the lower animals, tuberculosis, for example, and there is such a thing spoken of as typhoid fever in the horse. But there is no case I know of recorded where there is any reason to believe that the droppings of cows, or of any of the lower animals whatsoever, have produced typhoid fever. I think if that were not so we should have a good deal more typhoid than we now have, because there is hardly a surface water about the country that does not have more or less cow dung in it. It is a favorite habit of water works superintendents, in order to make things look pretty, to manure the banks of their reservoirs with cow dung, and there is no doubt that it helps the grass, but there is also no doubt it lets a good many of

the so-called fæcal bacteria into the water. I am not one of those who holds that the presence of fæeal bacteria, such as are commonly found in the lower animals, as well as in man, in a water supply testifies to the presence of human excrement. It may very often, and does, of course, testify to the presence of excrement of some sort, but not necessarily human excrement. And I am very glad to make that statement, because I think there are some bacteriologists who, whenever they find an intestinal bacillus in a water supply, hold that that is *prima facie* evidence of human contamination. I do not see how they can do so, because it is well known that many of the lower animals contain these same germs, or germs not readily distinguishable from our own. We haven't our own private baeilli in our intestines, but we are like the lower animals, our relatives, in having these particular parasites, — which perhaps are not parasites but messmates. I do not believe that there is any evidence whatsoever that cow droppings or horse droppings are able to produce typhoid fever or any other disease that we know of.

Of course, that is a comforting fact, because we unquestionably take in every day, or nearly every day, more or less of these things, either in water or in milk or in the dust of the street. Anyone, for example, who goes upon the Back Bay on a dusty day, and faees one of the dust storms that disgrace our city, has his lungs feeling like a dry furnace box, and undoubtedly hundreds — I know whereof I speak, because I have made examinations of the air — hundreds, and even thousands of these bacteria from dried up horse dung get into our mouths, and some of them into our stomachs. But it is not thought that any of these are likely to produce typhoid fever. The only source of typhoid fever known to-day is the intestine, — or I will say the body, in order to cover everything; the only soure known to-day is the body of a person having typhoid fever and, of course, particularly his excrement. If the latter gets into drinking water it is a serious thing.

Mr. Holden. Mr. President, I would like to inquire why it is that usually there are relatively a small number of people who contract typhoid fever, in a town or city, using water from a contaminated reservoir?

Prof. Sedgwick. That is a very reasonable question and one that necessarily confronts anyone who looks at this matter dispassionately. Take that case of Plymouth, for example. There was an unques-

tionably polluted supply, and yet out of 8,000 people only 1,200 came down with typhoid fever. I say only 1,200; that is enough, perhaps, but how about the others? Why are not more attacked? The number attacked is generally less than one per cent of the population, though, in the case of Lowell, in 1890–91, there were, I believe, about 1,000 cases of typhoid fever in the city, in round numbers, out of 78,000 people living there at the time. Only one in seventy-eight came down with the disease. Why was this, when the water was presumably pretty thoroughly infected?

Well, in the first place, not every tumbler of water, of course, contains the germs. An infection means an almost infinite diffusion of small particles, yet not quite an infinite diffusion. These germs have size and weight. If anyone were to let into the Merrimac, for instance, at Nashua or Manchester, an almost unlimited number of embryo fishes as big as pins, by the time they got down to Lowell, if you dipped out a tumblerful of water you wouldn't get many of them. There is great dilution to begin with, and not every glass at such times, and perhaps not even every pitcherful, contains the germs.

In the second place, there are a number of people who don't drink any water. There are a good many children, for instance, little children, who are fed mainly on milk, and perhaps never take a drink of water, very young children, I mean. Then there are old men and old women who are sitting about and not doing much, who don't drink much water. Again, not all ages are susceptible.

And then, once more, after we have made all these deductions, it must be confessed that in the present state of our ignorance we don't know how many of the germs it takes to make an effective dose. I believe from what evidence there is that a good deal depends on the dose. I believe if I were to pass around here, for instance, a polluted water, infected water, if it was not too richly infected and I could persuade the members of the Association to take a drink of water, that a very considerable proportion would actually receive these germs without any bad effects. There is what physiologists call "vital resistance." Nobody knows much about it except that it exists. On a fine, bright morning, when a man has had a good rest and everything is just right, and when he feels, as he says, "Like a fighting cock;" when his tissues are in such a condition that he can do almost anything, when it would be dangerous for anyone to propose to knock a chip off his shoulder; at such a time I

believe that a man could take a moderate dose of these germs, or perhaps even a large dose, and come out unscathed. But on the other hand, there are times when a man feels, as he says, "Like a boiled owl," when he is "run down," "played out," "overworked," and has n't had a good night's rest; when the world is "using him wrong," and it is a "blue day," perhaps when his tissues are in a bad condition. We believe these to be actual physical conditions, when the blood and the tissues and the whole organism are not working up to the mark, and there is something wrong somewhere. At such a time I should be very sorry to give a man even one disease germ, because the chances are that he would come down with the disease.

And taking a community at large, with thousands of people, and making these various deductions, I believe the thing comes out just about as it ought to. We know that when the dose is big, as it was in the case of Plymouth, the results are big, and when the dose has in other cases been small, the results have been small. As a physiologist and bacteriologist I have never felt any serious difficulty in this direction. I believe the facts fit together and are about what we should expect, and that with a well regulated body we ought to be able to take in some disease germs and overcome them: but at other times, when we are run down, we should (and do) get into trouble.

One of the first things that a man who investigates a typhoid fever epidemic discovers is that in fifteen cases out of twenty, if he inquires, the victim had been complaining not only for the couple of weeks when he should have been complaining, but for many weeks before. It is the commonest kind of experience in such cases for people to say so. It is one of the questions I have on my blank, "How had he been in health before he was taken sick?" And the answer in fifteen cases out of twenty certainly, is, "Well, he had n't been well for a good many months, he had been working too hard and he was run down"; and people generally add, "the disease had been coming on for several months." Of course, the disease had not been coming on for several months, because the period of incubation, as we call it, is at the outside, probably, only three weeks from the time the germs are taken. But the point nevertheless was true. He had been run down for several months, when finally the germ happened to come along and caught him off guard,

so to speak. At the same time perhaps another germ may have struck his neighbor who was strong and well, the run-down man succumbing while the strong man went safely through the battle. It is just as it is in war. The strong and the well endure ; the weak and the sickly perish. Armies lose more from sickness, you know, than from bullets, and we might say the same of the combatants with a typhoid infection.

Mr. Richards. I think we owe Professor Sedgwick a debt of gratitude for the exceedingly practical way in which he has explained this matter. I would like to emphasize one point, and that is the danger from boating, which seems to me to be greater than any other danger, for this reason : the pollution from boats is likely to occur right at the in-take and we may then have, so to speak, a concentrated extract right at the point where it will do the most harm. I have recently had a good deal of opposition in trying to stop boating on our storage reservoir. I considered it a real danger, whereas the danger from pollutions from farm houses was, perhaps, more remote.

It seems to be customary to wait until an epidemic occurs and then engage a bacteriologist to tell what caused it. How much better it is to remove the cause before the epidemic occurs, by prohibiting all boating and fishing on reservoirs and by keeping the residents on the watershed as few in numbers and as far removed from the reservoirs as possible.

Mr. McKenzie. Of course the Professor knows, as well as any of us, that it is very easy to detect polluted water and ice supplies when the sources of pollution are numerous ; but I would like to inquire if he knows of any State where they have laws by which Boards of Health, or other Boards, have judicial or mandatory powers to prevent such pollutions? Of course, in any State we can have made expensive chemical and bacteriological examinations of the water supplies, or we can discover in a practical way that they are polluted ; but how are we going to prevent the pollutions? Now, in Connecticut, and I suppose in other States, efforts have been made to have laws enacted which would give the supervision of water supplies to some authority, either to Boards of Health, or to some other Boards which might be created for that purpose, but such attempts have always been defeated. Of course, there are vested rights in manufacturing properties, and there are sources of pollution which have been long continued, and which people claim they have a

right to continue; and without employing expensive attorneys and expensive specialists it is diffcult to get any judicial decisions that will prevent such pollutions. What we want to know is how we can stop them.

Prof. Sedgwick. Well, Mr. President, in Massachusetts, — I don't know about Connecticut, although it happens to be my native State, — in Massachusetts it is a very simple matter, because so far as managing the boating and fishing is concerned, — the vested rights I know nothing about, — any local board of health in Massachusetts can, by passing an ordinance, that such and such things shall not be done under penalty, make that the law, so that so much is very easily managed. With regard to vested rights, I suppose there is nothing to be done except to buy the owners out, and it is expensive. But I think one of the notions we have got to get over in water supply service is the idea that good water is cheap. We have grown up with that idea in this country, and it came from the time when we thought a stream purified itself by running a little distance. Lowell and Lawrence certainly would never have stuck their intake pipes down into the nearest stream, sewage polluted as it obviously was, if they had n't supposed they were to get fairly good water, very good water in fact; and Chicago would never have supplied the enormous number of gallons per capita that it does supply if it had supposed at the start that it had got to look out for a pure supply. Unfortunately science at that time was not far enough advanced for any one to know, and people believed that they were getting good water if it looked clear and tasted well. That led them to believe that they were entitled to any amount of good water for nothing, or next to nothing. As populations thicken, manufactories multiply, and the consumption of water increases, if it unfortunately does increase, we and they have got to get over that notion. People, communities, have got to learn that if they are going to have plenty of good water they have got to pay for it. They must either limit the quantity, or else the quality, as the country fills up. And I think an Association like this is doing and can do great work in stating these facts frankly and fully to the people. There are cases where chemical and bacteriological examinations do not necessarily help us very much. If you see sewage running right into a water supply you don't need any chemical examination or biological examination. We have learned to meet that more serious, more obvious problem, but I think the sooner it is

distinctly understood that good water, like everything good, is going to cost a good deal, the better for all concerned.

Mr. FULLER. Will Professor Sedgwick just say a word in regard to ice which is taken, we will say, from a pond which is fed by a stream which has a considerable population upon it. How much danger there is from such ice?

Prof. SEDGWICK. Well, of course, I can only make very general statements in regard to such a case. The State Board of Health made a careful examination of the ice supplies of this State a few years ago, and the results are published in full in one of the reports, I think for the year 1889. It was led to make it by the discovery of Professor Prudden of New York, that much of the ice supplied to New York City was so rich in bacteria, appearing to be hardly more than frozen sewage, that it constituted a real menace to the health of the people. The upshot of the investigations in Massachusetts was that there were very few, if any, really objectionable, or at least, dangerous, ice supplies; that ice does purify itself to a remarkable extent when produced under favorable conditions; but that if produced by chopping holes through a thin sheet of ice and allowing water to flow over and freeze up solid, or if it is full of bubbly or snowy ice, it may be objectionable.

I confess I have always felt that the case of New York was somewhat exaggerated. Professor Prudden is a very good friend of mine, and in saying this I do not reflect upon him at all. He is an admirable bacteriologist. But it seems to me his results proved a little too much. If the state of affairs was as bad as he said it was, New York City, instead of having one of the lowest typhoid death rates, should have had a pretty high one, and I have always thought the facts did not wholly fit his observations. But then, again, it must be remembered that that particular ice was very peculiar. It was cut on the Albany basin, that is on a tidal stream just below the city of Albany, where the Hudson River is highly polluted with the sewage of Albany and Troy, the Mohawk Valley and so forth, and it was made by chopping holes through the ice and allowing the water to flow on, and then freezing it up solid. In other words, it came pretty near being frozen sewage; as near, probably, as ice ever could be anywhere. And yet after that ice had been cut and delivered in New York, New York has had, and did have, and does still have, a remarkably low death rate from typhoid fever.

I personally am not much of a believer in the dangers from ice, but in any particular case I should want to know what the character of the stream coming in was; whether the ice was obtained by bathing the cakes in sewage which was allowed to run over their surface; whether, in fact, it was sewage; and a lot of details which could easily be looked up. But if it was cut at the other end from where the brook came in, so that it took a long time for the water to get there, and if the ice formed first in a thin layer and produced stillness so that sedimentation would go on below, and then was added to, little by little, *from below*, always by the freezing of the purest water, because sedimentation had taken place underneath, and without chopping holes and flowing the water over it, I should have no hesitation in using the ice. I tell my students if they ever get into any place where they cannot get any decent water and can get good ice, if they will take a piece of pure ice and melt it and drink it, they will probably have as good water as they can have without boiling it. I should certainly do that myself if I were placed under such circumstances.

Mr. Doane. I would like to know as to the quality of ground water supplies, near polluted streams, particularly from filter basins, with only a comparatively thin wall of earth between, whether there would be a likelihood of the germs working through the sand for a short distance?

Prof. Sedgwick. Of course, each case would require special investigation, and fortunately in this State we have a State Board of Health ready to make such investigations on requests from the proper authorities. But it seems to me that the experiments at Lawrence have shown very conclusively that a few feet of good filtering material are a wonderful safeguard. Of course what is good filtering material must be considered carefully in regard to any particular case, and the conditions must be known, and the question of sufficient ogygenation, etc., considered. In regard to a filter basin running alongside a stream, as a rule, that is supposed not to draw so much from the stream as from the shore side. It is more like a well of water. All I can say is, that I have been studying this matter for some time, and I have never yet seen any cases, such as were suggested, of contamination of that sort. And personally I am rather skeptical about the pollution of wells unless from the surface. If there is good filtering material at the bottom I believe it acts really as a good safeguard, and that the dangers from a ground supply are comparatively

small. At the same time it must be borne in mind that the Caterham case was a ground supply. That was a well supply, and the simple introduction of a human being with an intestine full of typhoid germs into that well was sufficient to make great trouble. But then there, also, the trouble came in from the top. And I believe that in all cases, or in nearly all cases, the trouble from wells, except, of course, where there is a fissure right through the ground, comes from washing in at the top and not from filtering through the soil.

The PRESIDENT. Most of us are well aware that there are other diseases besides typhoid fever that are directly attributable to our stomachs. I would like to ask Professor Sedgwick if there is not perhaps equal danger of contracting some of the other stomach diseases from bacilli from human excrement?

Prof. SEDGWICK. That, of course, Mr. President, is a very interesting question, and we have had some pretty good chances to study it in Lowell and Lawrence, in the past, and in many other places. I suppose the thing would be stated fairly about like this: That there is little or no evidence that diphtheria, scarlet fever, cholera infantum, smallpox, consumption, or any similar diseases are carried by water. They may all be so carried, theoretically, and if the water were to move quickly enough they would be, probably. For instance, if a diphtheritic patient should spit in my tumbler here, while he had his throat full of the germs, and I should drink the water right down, there would be a pretty good chance of my getting the disease. But hospitals have frequently drained into water supplies — hospitals containing the stuff from old sores and from stomachs and mouths and all that — and the facts seem to show, the figures seem to show, that about the only diseases that are much carried by water are typhoid fever, Asiatic cholera, dysentery, and diarrhœa. I think I have named them all. It is commonly stated as the diarrhœal diseases, but the trouble with that is it is a little too broad, because the diarrhœal diseases include cholera infantum, and we have no evidence, at least hereabouts, of cholera infantum being carried in water. It seems as if it ought to be, but it is not, so far as the facts indicate. And all we can say by way of explanation is that apparently the typhoid and Asiatic cholera germs and diarrhœa and dysentery germs are tougher than the rest, and will stand water better than the other germs.

You must remember that it is a pretty uncomfortable situation for

a thrifty, warm-blooded bacterium, like a typhoid germ, to find himself in, when he passes from a warm human intestine, with plenty of good rich matter to feed upon, down into a water supply such as you gentlemen have charge of, pure and clear as crystal. It is a cold world that he is received into, and he is given the cold shoulder. The temperature is away below that which he prefers. Food is scarce. He may perhaps find rivals in the diatoms and infusoria present; the infusoria often feed upon bacteria, and the first thing he knows he may be eaten up. But, if not, he has weight and he finds himself settling to the bottom, and getting tangled up in the water weeds there. Then, again, the light is antiseptic and hostile to him, and the first thing he knows there is too much light. He has been in a dark, warm chamber, the intestine, with rich food, richer than sewage, much richer, infinitely richer, to feed upon. He has been in the human sewer, which is so much richer than any city sewer in its contents that it makes a special feeding ground for these things. Now, imagine a bacterium taken out of this luxurious living, and put into the cold world, where the temperature is wrong, and food is scarce, and enemies are numerous, and troubles visit him on every hand. It appears to be only the tough ones who can stand it, and there is some evidence that the typhoid and Asiatic cholera germs are particularly tough. At any rate, so far as I know, the facts do not lead us to believe that there are many water-borne diseases other than those I have mentioned, at least in this latitude. For instance, there is no good evidence that malaria is conveyed by water, and yet possibly it may be. The only safe ground to take in these matters is that up to date our knowledge indicates about what I have suggested; but our knowledge, like railway time tables, is "subject to change without notice."

Mr. Hazen. Mr. President, in this connection I would like to state in regard to cholera infantum (which is, of course, a subject about which I know nothing myself), that my friend, Dr. Reincke,* Health Commissioner of Hamburg, Germany, who has been studying this question for years, has come to the conclusion that cholera infantum is caused by bad water; and I have in my office quite a pile of German documents which show, by elaborate statistics, among other things, that cholera infantum is conveyed by water, and goes up

---

* Filtration of Public Water Supplies, page 144.

whenever typhoid goes up. Both have been reduced very much since the introduction of the filtered water supply in Hamburg, and not only have typhoid and cholera infantum decreased, but many other diseases have been decreased in a most surprising manner. The Doctor is unable to account for all of it, and he simply records the greatly decreased death rates as matters of fact.

PROCEEDINGS.

QUARTERLY MEETING.

Young's Hotel,
Boston, Dec. 9, 1896.

President Haskell in the chair.

The following members and guests were present: —

ACTIVE MEMBERS.

Solon M. Allis, Geo. I. Bailey, Lewis M. Bancroft, Frank A. Barbour, George E. Batchelder, Oren B. Bates, Joseph E. Beals, James F. Bigelow, Forrest E. Bisbee, Gerald M. Bliss, George Bowers, John T. Cavanagh, George F. Chace, E. J. Chadbourne, Henry Chandler, John C. Chase, Harry W. Clark, Freeman C. Coffin, R. C. P. Coggeshall, H. W. Conant, Byron I. Cook, Henry A. Cook, John W. Crawford, A. O. Doane, Harrison P. Eddy, Loring N. Farnum, B. R. Felton, Charles R. Felton, F. F. Forbes, Frank L. Fuller, L. L. Gerry, Fred B. Gleason, Albert S. Glover, Frederick W. Gow, E. H. Gowing, John C. Haskell, V. C. Hastings, Arthur Elliot Hatch, George Mason Hawes, Allen Hazen, Horace G. Holden, Horatio N. Hyde, William S. Johnson, Willard Kent, Patrick Kieran, George A. Kimball, Morris Knowles, James W. Locke, Arthur J. L. Loretz, Cyrus M. Lunt, William J. Luther, Arthur D. Marble, Theodore H. McKenzie, William McNally, Thomas Naylor, Edward C. Nichols, Frank L. Northrop, Walter H. Richards, George J. Ries, W. W. Robertson, Harley E. Royce, A. H. Salisbury, William T. Sedgwick, John E. Smith, George A. Stacey, Frederic P. Stearns, Frederick L. Taylor, Lucian A. Taylor, Robert J. Thomas, D. N. Tower, Charles K. Walker, John C. Whitney, Geo. E. Wilde, G. E. Winslow, W. G. Zick.

HONORARY MEMBER.

"The Engineering Record," by C. J. Underwood.

ASSOCIATE MEMBERS.

Ashton Valve Company, by Mr. Dill.
Chapman Valve Manufacturing Company, by E. L. Ross.
Deane Steam Pump Company, by F. H. Hayes.
George E. Gilchrist, by H. N. Libbey.
Ludlow Manufacturing Company, H. F. Gould.

Michigan Brass and Iron Works, H. H. Kinsey.
Perrin, Seamans & Co., by Harold L. Bond.
Union Water Meter Company, by J. P. K. Otis and Geo. P. Carr.
R. D. Wood & Co., by Jesse Garrett.
The Geo. Woodman Company, by H. A. Gorham.
H. R. Worthington, by J. M. Betton and E. H. Foster.

GUESTS.

J. E. Bunting, C. H. Collins, A. Dunbar, J. L. Dwyer, A. Holman, Alex. McClurg, G. E. Putnam.

The Secretary read the following names of applicants for membership, recommended by the Executive Committee :—

RESIDENT ACTIVE.

John C. MacMurray, Worcester, Mass., President and General Manager of the Cherryvale Water Company, Cherryvale, Kan.
George Mason Hawes, Fall River, Civil and Mechanical Engineer.
Cyrus M. Lunt, Superintendent Water Works, Lewiston, Me.
Frank E. Merrill, Clerk, Somerville Water Board, Somerville, Mass.

NON-RESIDENT.

Arthur J. L. Loretz, M. E., Brooklyn, N. Y., Designer of Pumping Machinery.
Charles D. Bettes, Far Rockaway, L. I., Engineer in charge of Queen's County Water Company.

ASSOCIATE.

Charles A. Moore, New York City, Manufacturer of Steam Engines and Boiler Specialties and Iron Working Tools.
H. F. Gould, Boston, Mass., Ludlow Valve Manufacturing Company of Troy, N. Y.

On motion of Mr. Thomas, the Secretary was directed to cast the ballot of the Association in favor of the above-named applicants and they were declared elected members of the Association.

Prof. W. T. Sedgwick, of the Massachusetts Institute of Technology, addressed the Association on "The Protection of Surface Waters from Pollution." Messrs. Holden, Richards, McKenzie, Fuller, Doane, Hazen and the President participated in the discussion of the subject.

Arthur J. L. Loretz, M. E., of Brooklyn, N. Y., read a paper entitled "Pumping Engines."

Adjourned.

ADJOURNED MEETING.

Young's Hotel,
Boston, Jan. 13, 1897.

President Haskell in the chair.

The following members and guests were present: —

ACTIVE MEMBERS.

Everett L. Abbott, Solon M. Allis, Charles H. Baldwin, Lewis M. Bancroft, George E. Batchelder, Oren B. Bates, James F. Bigelow, George Bowers, Dexter Brackett, James Burnie, George F. Chace, E. J. Chadbourne, John C. Chase, Harry W. Clark, Greeman C. Coffin, R. C. P. Coggeshall, H. W. Conant, Byron I. Cook, Henry A. Cook, F. H. Crandall, Lewis Cushing, Eben R. Dyer, Harrison P. Eddy, John W. Ellis, George E. Evans, B. R. Felton, F. F. Forbes, Frank L. Fuller, Julius C. Gilbert, Fred B. Gleason, T. C. Gleason, Albert S. Glover, J. A. Gould, Frederick W. Gow, John C. Haskell, Louis E. Hawes, T. G. Hazard, Jr., Allen Hazen, Horace G. Holden, Daniel D. Jackson, William S. Johnson, Willard Kent, Patrick Kieran, Frank C. Kimball, Morris Knowles, Perry Lawton, Wilbur F. Learned, James W. Locke, Arthur D. Marble, A. E. Martin, John C. MacMurray, Frank E. Merrill, Charles F. Murphy, Thomas Naylor, Frank L. Northrop, W. W. Robertson, A. H. Salisbury, William T. Sedgwick, George A. Stacey, Frederick P. Stearns, Frederick L. Taylor, Lucian A. Taylor, Robert J. Thomas, William H. Thomas, D. N. Tower, W. H. Vaughn, Charles K. Walker, J. Alfred Welch, John C. Whitney, George E. Winslow, E. T. Wiswall, W. G. Zick.

HONORARY MEMBERS.

"The Engineering Record," by C. J. Underwood, Jr.
"Fire and Water," by F. W. Shepperd.

ASSOCIATE MEMBERS.

Chadwick Lead Works, by A. H. Brodrick.
Chapman Valve Manufacturing Company, by E. L. Ross.
Deane Steam Pump Company, by F. H. Hayes.
Howe, S. G.
Ludlow Valve Manufacturing Company, H. F. Gould.
Michigan Brass and Iron Works, by H. H. Kinsey.
Thomson Meter Company, by S. D. Higley.
Union Water Meter Company, by J. P. K. Otis.
R. D. Wood & Co., by Jesse Garrett.
H. R. Worthington, by James M. Betton.

GUESTS.

J. D. Adams, T. E. Dwyer, F. E. Hunter, J. Edwin Jones, F. Pope, Geo. E. Putnam, Paul Sears, Thomas B. Tripp, Edmund Wood, Henry A. Wyman, Geo. D. Wemyss.

The Secretary read the following names of applicants for membership, recommended by the Executive Committee:

RESIDENT ACTIVE.

R. S. Bartlett, Superintendent Water Works, Norwich, Conn.
Edward I. Marvell, Civil Engineer, Fall River, Mass.

ASSOCIATE.

Solon G. Howe, Manufacturer Tapping Machines, Detroit, Mich.

On motion duly carried the Secretary was directed to cast the ballot of the Association for the above-named candidates, and they were declared elected members of the Association.

A call was then made by the President for volunteer five and ten-minute experience papers for the February and March meetings, and he stated that he thought there was not a superintendent there who had not had some experience that would be novel and of value to all the rest of the members.

Mr. WALKER. I have had an awful experience. [*Applause.*] Things don't run so smoothly with me as they might, but I do not want to tell you of my affliction. I don't know but I might have something for the meeting in March. Anything that I know, I got from these meetings here, and I am thankful for it; but I cannot give it back. [*Laughter.*]

Mr. STACEY. I suppose, Mr. Walker's experience is on water works and nothing else. I feel as he does. I have got a large amount of information since I joined this Association, and it seems to me as though all of us have something at stake here, in trying to keep up to the mark, and extend the knowledge that we have received from others, and I will say that I will do so in this matter. I find that in looking over the Journal the short experience papers we have had in the past, have interested me about as much as any. There is always meat in them, and they occur to us oftentimes when we are in a tight pinch and do help us out. So, Mr. President, I will try to do what I can to push the good thing along. [*Applause.*]

Mr. Kieran. I likewise have learned a great deal from these meetings. If there is anything that I can give later on I will do so.

The President. I presume that in the course of a week or two you will all take the advice given by the Chair and send in notices of the titles of your papers. I know it is rather quick to think up all these experiences, but if you will send them in to us later, they will be just as acceptable.

The President then introduced Mr. Edmund Wood, member of the Water Board of New Bedford, who read a paper on the "Further Water Supply of the City of New Bedford, now being constructed." This paper was discussed by Mr. George E. Evans and many others. A paper was then read by Mr. Harry W. Clark, Chemist of the State Board of Health, on the "Removal of Iron from Ground Waters," which was discussed by Messrs. Hazen, Hawes and others. Mr. Stacey made the following remarks: —

THE VALUE OF WATER.

Mr. Stacey. There is a question I would like to ask. I ran up against an inquiry a while ago in regard to the financial part of water works management: as to whether it was a fair business way, or customary in making up the value of water works, to place any value on the water itself outside of the actual cost of construction. That is, saying that your water works cost you a certain sum of money in actual construction, and you have a supply sufficient for a city or town in the works, do you place any value on that water in making up the assets of the water works?

Mr. Whitney, Secretary. I can answer for the town of Newton at any rate, that they have never thought of taking water as an asset any more than the air that circulates through that vicinity.

The meeting then adjourned.

ADJOURNED MEETING.

Young's Hotel,
Boston, Feb. 10, 1897.

President Haskell in the chair.

Members and guests were present as follows : —

ACTIVE.

Everett L. Abbott. Chas. H. Baldwin, Lewis M. Bancroft, Geo. E. Batchelder. Oren B. Bates, Joseph E. Beals, Jas. F. Bigelow. Geo. Bowers, Arthur W. F. Brown, John T. Cavanagh. Geo. F. Chace. Henry Chandler, R. C. P. Coggeshall. Byron I. Cook, Henry A. Cook, F. H. Crandall, Francis W. Dean, A. O. Doane, George E. Evans, A. A. Fobes, Frank L. Fuller, Julius C. Gilbert, Amos A. Gould, Albert S. Glover, Frank E. Hall, John C. Haskell, Louis E. Hawes, T. G. Hazard, Jr., Horace G. Holden, Willard Kent, Patrick Kieran, Geo. A. Kimball, Horace Kingman, Morris Knowles, Jas. W. Locke. Jas. W. Morse, Frank E. Merrill, Fred'k L. Rice, Walter H. Richards. George J. Ries. W. W. Robertson. Henry W. Rogers. A. H. Salisbury, John E. Smith, George A. Stacey. Lucian A. Taylor, Robert J. Thomas, D. N. Tower, W. H. Vaughn. Chas K. Walker, J. Alfred Welch, John C. Whitney, Geo. E. Winslow, E. T. Wiswall. W. G. Zick.

HONORARY MEMBERS.

The "Engineering Record," by C. J. Underwood: "Fire and Water," by F. W. Shepperd.

ASSOCIATE MEMBERS.

Deane Steam Pump Company, by F. H. Hayes.
Ludlow Valve Manufacturing Company, by H. F. Gould.
Michigan Brass and Iron Works, by H. H. Kinsey.
New York Filter Company, by Chas. Wilson.
Perrin, Seamans & Company, by H. L. Bond.
Thomson Meter Company, by Secretary Folger.
Union Water Meter Company, by J. P. K. Otis.
Walworth Manufacturing Company, by G. E. Pickering.
The George Woodman Company, by H. A. Gorham.
H. R. Worthington, by J. M. Betton.

GUESTS.

Mr. Bancroft, Mr. Gibson, Geo. L. Chapin, John F. Hurley, A. L. Estabrook.

The following applications for membership were recommended by the Executive Committee, and upon a vote were elected members of the Association : —

RESIDENT ACTIVE.

E. C. Brooks, Acting Superintendent, Cambridge, Mass.

Leonard Metcalf, Professor Engineering, Massachusetts Agricultural College, Amherst, Mass.

T. F. Richardson, Department Engineer, Metropolitan Water Board, Clinton, Mass.

C. H. Eglee, Constructing Engineer, Boston, Mass.

Frank M. Cole, Meter Inspector, Brockton, Mass.

LIBRARY.

The Secretary stated that endeavors were being made to form a library, and that an important portion of that library would consist of reports of city and town water works. He hoped that the members of the Association, in preparing their annual reports, would bear this in mind and favor the Association library with copies.

The President then introduced Mr. John Hurley, President of the Salem Water Board, who spoke as follows : —

REMARKS OF MR. JOHN HURLEY.

Mr. President and Gentlemen : I am somewhat surprised that your President should call upon me. I am not as competent or able to talk upon water supplies as others who are here. I have attended three or four meetings of this Association, and it has afforded me considerable pleasure to be present with you, gentlemen. It is a school of education that is beneficial to any man who is in any way interested in water supply. I have received these invitations from the Superintendent of the Salem Water Works, Mr. Cook, and I have always accepted them, for I knew that I could learn something by being present at the meetings that would be a benefit to the Board of which I am President, — the Salem Water Board.

At one of the first meetings that I attended, I listened to an address by Mr. Desmond FitzGerald, of Boston, who told of a dam that he was building. I became very much interested in what he said, not

knowing that I would ever be elected as a member of a water board, but my attention was directed forcibly to it.

At the table where I sat was Mr. Lucian A. Taylor, a member of your Association, and when a short time afterwards the Salem Water Board asked the city of Salem to appropriate for its use $74,000 for an additional water supply, the services of Mr. Taylor were secured as consulting engineer, and I assure you, gentlemen, that Salem made no mistake. We have, through the water supply of Wenham Lake, an abundance for our needs, and we have planned for a supply for Beverly, which is connected with us.

But there is something, gentlemen, which I wish to call your attention to. We have received from a gentleman, — I think it was the President of the Cambridge Water Board, — a letter asking us to coöperate with him in appearing before the Legislature to protest against out-houses and cesspools being built too near bodies of water used for water supply. Salem petitioned to the Legislature to make the distance limit five hundred feet in order to protect the water from pollution. Beverly, which is somewhat connected with Salem, opposed it, and Salem could do nothing. Our own stable at our pumping station was within one hundred feet of the lake, and we were compelled to move it some five hundred feet back. Within the last week typhoid fever has broken out, and the cesspool of the house where the typhoid fever now exists is not five hundred feet away, and there are cesspools within one hundred and fifty feet of the water supply. I think it would be well for every gentleman here to appear before the Committee on Water Supply at the State House and protest and do what can be done to do away with all out-houses and cesspools within five hundred feet of lakes used for water supply.

Typhoid fever, before the introduction of water from Wenham Lake, was quite prevalent. We had forty-eight cases at one time, but since we have had our new supply there has not been a solitary case of typhoid fever in Salem.

We have had quite a controversy in Salem in regard to diphtheria. We have had forty-two cases. Of course it is not caused by the water, but in the forty-two cases that we have in Salem to-day there is not one left-handed child who has got the diphtheria, which is accounted for from the fact that they drink with the left hand and therefore drink from the other side of the dipper from what the right-handed children drink, so that they do not contract the disease from the right-handed children. [*Laughter.*]

Mr. Stacey of Marlboro, Mr. Walker of Manchester, Mr. Crandall of Burlington, Mr. F. L. Fuller of Boston, and Mr. Hawes of Boston then presented experience papers which were discussed.

Mr. Allis gave an interesting account of the breaking of pipes in winter in Malden. He decided to have them break at a more convenient season. The pipe was weak in places, and extra pressure at times was too much for it. Accordingly, at a convenient time in good weather, the pressure was raised considerable, and numerous breaks resulted. These were repaired at one fifth of the cost of repairing in winter. During the following winter care was exercised to avoid high pressure, and there were no breaks.

The meeting then adjourned.

Obituary.

James Hugh Stanwood, died May 25, 1896, aged 34 years. Joined the Association June 15, 1894.

Mr. Stanwood was a native of Maine, a graduate of the Massachusetts Institute of Technology in the class of 1887, and instructor of civil engineering in that school. He was a member of the Boston Society of Civil Engineers, and an associate member of the American Society of Civil Engineers.

Ezra Clark, died Sept. 26, 1896, aged 82 years. Joined the Association Dec. 14, 1887.

Mr. Clark had been President of the Hartford Water Board for sixteen years, during which time the work of building the reservoirs and system was largely accomplished. The Tumbledown Brook reservoir was first suggested and urged by Mr. Clark, and the reservoir park was also his planning.

Mr. Clark was a member of Congress from 1855 to 1859, and was always prominent in public affairs.

William E. Nason, died Oct. 10, 1896. Joined the Association June 16, 1886.

Mr. Nason was a veteran of the Civil War, and was instrumental in the construction of the water works of Franklin, N. H., of which he afterwards became Superintendent and had charge of at the time of his death.

Albert F. Noyes, died Oct. 12, 1896, aged 45 years. Joined the Association Dec. 3, 1884.

Mr. Noyes was one of the first to join the Association after its formation. He was a member of the Executive Committee, 1887–8, and was President, 1890–1. He presented papers which have been published by the Association, as follows: "Weight of Cast Iron Pipe," 1885, 154; "Driven Wells as a Means of Water Supply," Vol. I., 4; "Experience in Excavating in Quickstand," Vol. IV.,

218; "The Metropolitan Water Supply of Massachusetts," Vol. X., 117; also the President's annual address, Vol. VI., 5.

Mr. Noyes was a member of the Boston Society of Civil Engineers, which he served as Vice-President and afterward as President; of the Massachusetts Highway Association, of which he was Vice-President; of the American Society of Civil Engineers, and of the American Public Health Association. For seventeen years, ending in 1893, Mr. Noyes was City Engineer of Newton, and as such had much to do with the extensions and improvements of the Newton water works. Afterwards for two years he was Assistant Chief Engineer of the Massachusetts State Board of Health, and at the time of his death he was in private practice as consulting engineer, making a specialty of water works matters. He was also an alderman of Newton, and a member of the Metropolitan Sewerage Commission.

Mr. Noyes was a constant attendant of the meetings of the Association, and was ready to take part in the discussions and to help the work in any way. His straightforward honesty and good will made him a universal favorite, not only with the members of the Association, but with all who knew him; while his advice upon the most varied subjects was sought and prized because of his wide experience, close observation and sound common sense, and because it was always given freely and gladly and with an unselfishness which could be influenced by nothing but the best interests of those who sought his counsel.

Wilmer Reed, died November, 1896. Joined as an associate member January 8, 1890.

Mr. Reed was selling agent for the McNeal Pipe and Foundry Company, and was well known to the members.

HEADQUARTERS OF THE ASSOCIATION—TREMONT TEMPLE BUILDING, BOSTON.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

VOL. XI. JUNE, 1897. NO. 4.

REMOVAL OF IRON FROM GROUND WATERS.

BY HARRY W. CLARK, CHEMIST, IN CHARGE OF THE LAWRENCE EXPERIMENT STATION.

[*Read Jan.* 13, 1897.]

The occurrence of iron in some of the ground waters of the State in such amounts as to be objectionable is known to most of you by hearsay, and to some of you by experience. The fact has been frequently referred to in the reports of the State Board of Health, and in the report for 1895 an account is given of some experiments made by Mr. Desmond FitzGerald and Dr. Drown in regard to the removal of iron from the Reading water supply.

It has been known for some time that when the iron is present in the water in the form of a bicarbonate, that it can, by aeration and sand filtration, be removed quite completely from the water. When, however, it is present as a sulphate or protoxide of iron, the problem of its removal becomes much more difficult. Thus, with the Reading water, with the iron present in the form of a sulphate, exposure to the air, or even forced aeration, had generally little or no effect upon the iron contents of the water. Most of the iron would remain in solution, and could not be removed by sand filtration. Filtration through marble chips removed the iron, but increased the hardness of the water very considerably.

During last August I was asked by Mr. Goodnough, the chief engineer of the State Board of Health, to begin the study of another

water supply of the State containing a very excessive and objectionable amount of iron,— that of the town of Provincetown. This supply is taken from a system of tubular wells located about three fourths of a mile north of the centre of the village. The wells are five inches in diameter, average about twenty-eight feet in depth, and are sunk in loose sand, which contains more or less organic matter and iron. The wells were completed during the latter part of 1893. The amount of iron in the water has increased each year, being 0.1340 parts per 100,000 during 1893, 0.2212 during 1894, 0.3764 during 1895, and 0.4950 during that portion of 1896 in which my investigations were carried on at the Lawrence Experiment Station.

The removal of the iron by means of aeration and sand filtration was first studied. A small filter, containing four feet in depth of sand, was constructed, and the Provincetown water, having first been aerated by drawing a current of air through it, was applied to this filter at a rate of 1,000,000 gallons per acre daily. The filter was kept in operation for several weeks, and, as an average, 20 per cent of the iron was removed from the water.

Long continued aeration of the water did not affect or change the character of the iron in solution in it, and the filter was fully as effective when the water was applied to it without preliminary aeration. Reducing the rate of filtration to 100,000 gallons per acre daily, resulted in a removal of 80 per cent of the iron, but enough remained in solution to render the water turbid. Continuing the investigation, I found that the addition of an iron salt, such as ferric chloride or ferrous sulphate, caused a precipitation of a considerable portion of the iron in solution.

I also found that by passing the water through a filter composed of small pieces of iron, such as iron filings and turnings, that the ferrous hydrate formed by the water and iron-filtering material would unite with and precipitate the iron in the water to a remarkable extent, and that the iron could then be almost completely removed by subsequent sand filtration. This process for removing the iron could without doubt be used practically upon a large scale, and is somewhat similar to the Andersen process, where the water is shaken in iron revolvers with metallic iron, and the ferric hydrate formed, coagulates and precipitates the organic matter in the water. I have never heard of this process being used, however, for the purpose of removing iron.

Knowing the value of coke as a filtering medum, and knowing also, from experiments with it for a different purpose, that the small percentage of iron contained in it sometimes achieved remarkable results, a small filter containing 3.5 feet of coke breeze (the screenings from commercial coke), was put in operation Oct. 6. This filter was operated at a rate of 500,000 gallons per acre daily at first, and afterwards at the rate of 1,000,000 gallons per acre daily, and at both rates 98 per cent of the iron was removed from the water. The filter was continued in operation for several months, and the effluent was always clear, practically colorless, and the very small amount of iron in it remained in solution.

The coke in this filter was obtained from the Lawrence gas works, and additional filters operated for shorter periods, and containing coke from different gas works, and also metallurgical coke, gave equally good results.

Wishing to test the efficiency of this method upon a larger scale, a filter was constructed at Provincetown, 13.7 feet in diameter, that is, $\frac{1}{300}$ of an acre in area, and containing 3.5 feet in depth of coke breeze. This filter has been in operation for about three weeks, and for most of that period at a rate of 1,000,000 gallons per acre daily, and has removed 93 per cent of the iron of the applied water, as shown by the samples collected.

This result is not quite equal to that obtained upon a smaller scale at the experiment station, and is due to three causes: shallower depth of filtering material, poor distribution of the applied water (causing at times high rates of filtration through a small portion of the filter), and lower temperature.

The distributing apparatus has been improved during the past few days, and better work is expected. As for temperature, it is quite evident that the iron remains in solution better in winter than in summer. The water drawn from the taps in Provincetown in winter being much less turbid and not so highly colored as in summer, although containing fully as much iron. If allowed to stand in a warm room, however, the water soon becomes much more highly colored; but only a very slight separation and settling out of iron takes place during any season of the year, and gallon bottles of the water have stood in my laboratory week after week without change.

In regard to the action of the coke filters in removing iron, and their great efficiency as compared with sand filters, it can be said that

besides the mechanical actions of the very porous and rough particles of coke, which undoubtedly cause the removal of a large percentage of iron, its almost complete transformation into a body easily filtered out I consider to be due to a chemical action caused by the metallic iron in the coke. By means of this iron, just as by the iron filings in the filter previously described, the formation of ferrous hydrate is initiated, and this, during its formation, perhaps, acts upon the iron in solution in the water, changing it to ferrous and then to ferric hydrate, and in this form it is easily filtered out.

In conclusion, I would say that the use of coke in the purification of iron-bearing waters is not new, but whenever used previously has been largely if not entirely simply as a medium through which to pass the water for purposes of aeration, the removal of iron being subsequently accomplished by sand filtration, coarse coke being used in these instances instead of the fine breeze, such as I have used.

DISCUSSION.

Mr. Hazen. I am very sorry that Mr. Bettes, the engineer and superintendent of the Queen's County Water Company of Far Rockaway, Long Island, is not here, because I was very anxious to have him tell you of the results that have been accomplished in taking the iron out of their water supply.

Mr. Clark has certainly done us a great service in showing the nature of the action of coke in removing iron from ground waters. Coke has been used, as Mr. Clark says, in nearly all of the German plants for removing iron, but I do not think that the chemical actions taking place have ever previously been pointed out.

This question of the removal of iron from ground waters is quite new in the United States. In Northern Europe it has been a live question for many years. Through the northern part of Germany, which is very flat and sandy, and also in the dunes of Holland, ground water is obtained freely and of most excellent quality in all respects except that it very often contains iron. Formerly this fact often led to the rejection of ground water supplies and the use of filtered river waters; but in recent years the great progress that has been made in removing iron has resulted in the use of these waters by many large municipalities.

A word in regard to the source and condition of the iron may be of interest to some of the members not familiar with it. Nearly all sand and soil contains iron in very considerable quantity. When water stands in, or passes through these materials, as long as free oxygen is present the iron remains in a ferric condition and is then entirely insoluble, and the water drawn from such strata is free from iron, nothwithstanding the fact that it has been in contact with large quantities of that substance. If, however, for any reason the supply of oxygen becomes exhausted in the ground, the organic matters often present in the soil or in the water reduce some of the iron in the ground to the ferrous state; that is, some of the oxygen in combination with the iron is taken away by the organic matters, which become partially oxidized by the process. The iron in the reduced or ferrous state is quite soluble in waters containing a little carbonic acid, as most ground waters do, and under these conditions the water drawn from such strata contains iron in solution, usually in the form of ferrous carbonate.

The solution of iron depends upon the existence or absence of the oxygen in the ground. Iron is almost always present in any material from which water supplies are drawn in sufficient quantity if dissolved to render the water passing through objectionable from iron for long periods, probably for centuries; and the trouble arises not from the presence of this iron in the ground, but from the conditions in the ground and in the water favorable for the solution of the iron.

This iron is objectionable in a water supply from its taste, and from its astringent action upon the system; from its disagreeable appearance, as it slowly precipitates out, discoloring the water; and from the fact that when used in the laundry it has a strong tendency to separate in the fibre of cloths, coloring them a dirty yellow brown, and when once colored, there is apparently no way of getting it out of the fibre: the color is as durable as the cloth itself.

The methods of removing the iron usually followed are very simple, and are exactly the reverse of the conditions which result in the solution of the iron in the ground. The water is brought in contact with an excess of air to oxidize the soluble ferrous iron up to the insoluble ferric form, which is then readily separated. The iron does not combine with the air at once when it is brought in contact with it, and although it will eventually all be oxidized, it is nevertheless possible to thoroughly aerate ground water and to keep it aerated for some

hours without oxidizing any appreciable amount of the iron. The presence of some other substance not in itself taking part in the reaction is apparently necessary to cause a prompt oxidation of the iron. Such a substance is furnished in the German works by the coke in the coke towers, which at once aerate and cause the oxidation of the iron. In other cases the surface of the sand in the filter answers this purpose; and I have found by some experiments during the past year that in some cases this oxidation on the surface of the filter is almost instantaneous. The water above the filtering material contained plenty of oxygen in solution, but all of the iron was in solution in the ferrous state, no oxidation having taken place. Immediately after entering the filtering material the iron had all been removed as ferric hydrate, and only the slightest trace of iron remained in solution.

The waters which Mr. Clark has mentioned seem to be peculiar, in that the iron is present, in part at least, in the form of ferric sulphate or at least as a compound more stable than the carbonate, and cannot be removed with the readiness with which it can be when in the form of a carbonate. This condition of affairs has not, so far as I know, been encountered in any of the foreign works; and we shall await with much interest developments as to how common it is likely to be in this country.

Some of the largest and most interesting works for the removal of iron are those at Kiel, at Charlottenburg and at Leipzig in Germany, and at Hague and Amsterdam in Holland. In the older Dutch plants the water was simply aerated and then filtered through sand. In the German plants the water was passed through coke very rapidly, many times as rapidly as in Mr. Clark's experiments, and it was found in this way that the water was aerated and the iron was largely oxidized and partially removed; but to take out the remainder of the iron and render the water bright and clear, it is necessary to afterwards pass it through sand at rates from five to ten times as great as are employed in ordinary sand filtration.

At Far Rockaway the coke tower was dispensed with, and it was decided to try the sand filters alone as an experiment, and it was found that they removed all of the iron, and no further treatment was necessary. The rate of filtration was only somewhat greater than that followed in the filtration of surface waters, because it was desired to use at times the water from certain brooks, and it was thought best

to use a rate of filtration which would be adapted to the purification of these waters as well as to the removal of iron.

Mr. Hawes. I would like to ask Mr. Clark if there was any examination made of the ground water in the vicinity of the pipe wells, but outside of the system of wells and distribution piping, for the purpose of ascertaining what changes may have taken place in the condition of the water in the ground.

Mr. Clark. I cannot answer that very completely, but I think that the water was examined in a number of places outside of this system. That was in 1893, and I had nothing to do with it then. I think Mr. Johnson can tell you about that.

Mr. Hawes. My reason for asking the question was because of the peculiar conditions at Provincetown. There has always been a question in my mind as to the effect upon the water in the ground when there has been a draft upon the supply by means of the wells, whether or not the water would deteriorate or improve. Quite recently test wells have been put down near the station, as I understand from the superintendent, and water pumped from them. At places where, during the preliminary investigations in 1892, water with considerable color and odor was obtained, at this time the water was found to be improved. It is in the vicinity of the large wells, and of course the improvement was only noticed by observation and not by chemical analysis, the water appearing colorless and free from odor.

I am desirous of knowing if the increase in the quantity of iron, as ascertained by chemical analysis, was in the water taken from the works, or from the ground, or both, so as to show whether or not the additional quantity of iron was in any way due to the system itself; that is, if the metallic iron of the pipes or standpipe in any way contributed to the quantity.

Mr. Clark. The water analyzed just as pumped shows an increase of iron almost every month, year after year,—a slight increase. Certainly that cannot be due to any part of the system except the wells themselves. There is no increase as it goes from the pumping station to the houses. I had, during the fall, samples from three parts of the system, (1) the pumping house, (2) as it comes from the standpipe, and (3) the taps in the town; and the iron averages just about the same. That is, one week you might get it a little more from the town than the well, and another week you would not, so the average of the three places would be about the same.

A Member. Have I understood Mr. Clark rightly that iron in the form of sulphate was not removed by sand filtration, and then later the addition of the sulphate caused removal? I did not get that clear.

Mr. Clark. Iron in the form of sulphate, as is the case at Reading, cannot be removed by simple aeration and filtration. But if we have water with iron in a different form, as in Provincetown, and add the ferrous sulphate to it we get ferric hydrate in the water, which will precipitate and then can be filtered out.

A Member. I would like to know if the filtration used at Reading was intermittent filtration.

Mr. Clark. I think it was operated intermittently at times, and at times continuously. With the Provincetown water, as I said, — and I think the same thing can be said in regard to the Reading water, — running the filter at as low a rate as 60,000 gallons resulted in a removal of from 80 to 90 per cent of iron; but the idea is, if you can, to run the filter at a higher rate.

ASHLAND FILTERS COMPARTMENT NO. 1. INTERIOR VIEW, SHOWING COMPLETED MASONRY READY TO RECEIVE FILTER BED.

ASHLAND FILTERS. COMPARTMENT NO. 2. OBLIQUE INTERIOR VIEW OF GRO'NED VAULTING, WITH FILTER BED COMPLETED.

ASHLAND FILTERS, COMPARTMENT NO. 3 INTERIOR VIEW OF VAULTING, SHOWING FILTER BED PARTIALLY COMPLETED.

THE WATER SUPPLY OF PROVINCETOWN, MASS.

BY LOUIS E. HAWES, C. E., BOSTON, MASS.

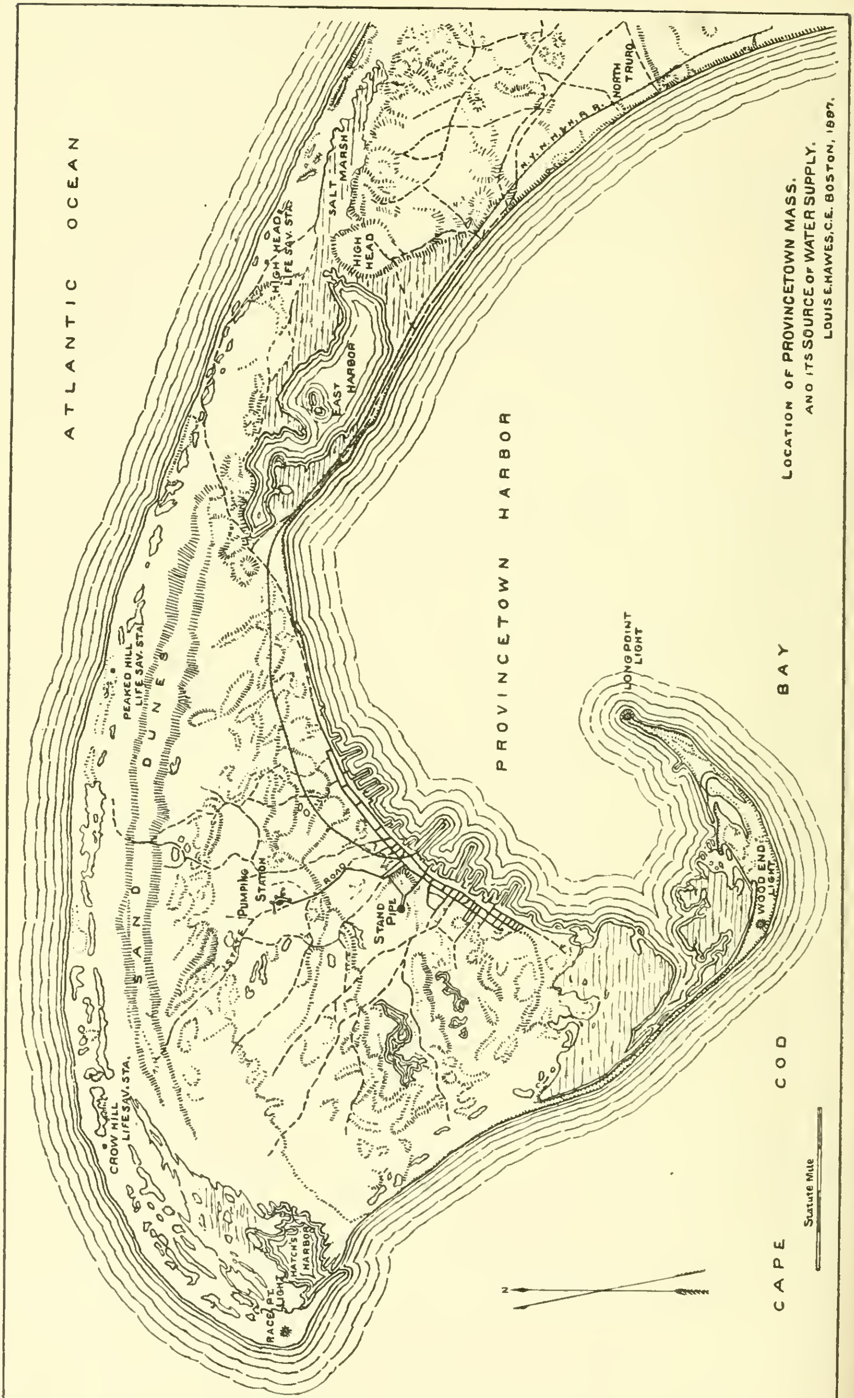
[*Read Feb.* 10, 1897.]

In view of the experiments upon the removal of iron from the water at Provincetown, now being conducted by Mr. Harry W. Clark for the State Board of Health l the unusual character of the water as mentioned in the Twenty-f urth Annual Report of the Board, a brief description of the source of supply may be of interest. I have prepared the following from observations made during the preliminary investigations for the sup ly in 1892 and the construction of the works in 1893, and have added a few remarks concerning the iron in the water, based upon my recollection of the circumstances and information which has reached me, but without special study since the works were built.

The location of the town is practically in mid-ocean. Situated on the extremity of Cape Cod, it is almost surrounded by the sea, and some twenty miles east of the mainland across Cape Cod Bay. The broadened end of the cape, with an arm that extends from it in a peculiar manner, forms on its southerly side what is considered one of the finest harbors of refuge in the world. This broadened end has an area of seven or eight square miles, the inhabited portion of the town extending along the harbor for a distance of about two miles east and west, and a quarter to a third of a mile northerly from the shore.

From the nature of the formation and various observations that have been made, this territory is supposed to have been open sea at some time previous to our knowledge of the conditions; the advent of the present land appearing to have been gradual and caused by the action of wind and water upon the lighter particles of the cape formation. This action has piled the sand into huge drifts or ridges, with valleys and plains intervening, the material forming the entire region above sea level, as far as known, being a uniform grade of sand, without clay, stones or rocks of any description.

This theory of formation received some corroboration during the investigation for water-works in the shape of smooth, water-worn


ATLANTIC OCEAN
PROVINCETOWN HARBOR
CAPE COD BAY
SAND DUNES
SALT MARSH
HIGH HEAD LIFE SAV. STA.
HIGH HEAD
EAST HARBOR
N.Y.N.H.&H.R.R.
NORTH TRURO
PEAKED HILL LIFE SAV. STA.
CROW HILL LIFE SAV. STA.
PUMPING STATION
STATE ROAD
STAND PIPE
LONG POINT LIGHT
WOOD END LIGHT
RACE PT. LIGHT
HATCH'S HARBOR
N
Statute Mile
LOCATION OF PROVINCETOWN MASS.
AND ITS SOURCE OF WATER SUPPLY.
LOUIS E. HAWES, C.E. BOSTON, 1897.

beach stones, which were taken from a well at about the depth of low tide, and situated a mile inland, indicating wave action at some remote time in that locality; also from the fact that in driving pipes through the loose sand, the backbone or compact material underlying the territory was invariably reached at a somewhat uniform depth below mean sea level, the loose sand above varying but little in its physical appearance.

At the narrow neck connecting the broad end with the rest of the cape is a shallow body of water called East Harbor, which has been enclosed or separated from the large harbor by a dike and the railroad constructed across it. Although its water was formerly salt, it has now become fresh, the transition having been gradually effected in nature's laboratory through the agencies of evaporation, rainfall, and the movement of the tides. As high tides have been known to sweep entirely over the narrow land separating East Harbor from the Atlantic Ocean, it is not at all improbable that the present end of the cape may have been an island at some period in its existence. From East Harbor, southerly, beginning at what is called High Head in the town of Truro, where the formation changes abruptly, the material is in accordance with the more usual New England formation, appearing, however, to be mainly sand and gravel.

At Provincetown the surface is covered with vegetation and well wooded in places, except on the Atlantic Ocean side of the cape, where the moving of the sand with every wind storm is still in progress, burying what little vegetation has secured a foothold and occasionally covering sizable trees, leaving only their tops visible.

The scene is well worth a special trip to the "Backside," as this part of the cape is called in Provincetown, and the locality is annually visited by many; the new State road through the Province Lands to the Sand Dunes making the region more accessible than formerly.

During the process of formation, organic matter of marine origin below sea level, and surface vegetation above, have doubtless been covered by the shifting sand, and slowly decomposing since, now impart color and odor to the ground water where such matter was located. As suggested by the appearance of marine growths observable on the harbor bottom in shallow water, and the varied quality of the ground water within short distances, it is probable that the organic matter occurs in irregular patches and with no uniformity of distribution.

Aside from the water in the ground, — which is in abundant quantity and nearly level from sea to sea at about the elevation of high tide, and which, if the theory of formation mentioned is correct, has replaced the salt water formerly there, — and a few very shallow ponds of stagnant water, no important body of fresh water is within reach of Provincetown for its water supply. Consequently there was no option but to secure a ground water source.

In determining the best place from which to take the water, some forty-five test wells were driven in various places through the loose sand. The effect of decomposed organic matter was frequently apparent in the water found, and occasionally, when present in large quantities not completely decomposed, could be seen by the naked eye as minute brown or black particles having organic characteristics. Hence it became a problem of finding the greatest area within which the water was of the best quality. This was determined to be at the present location of the pumping plant, which is situated in a valley or plain about three fourths of a mile inland from the village, the water at this place being more uniformly good than elsewhere, free from the contaminating influences of habitations, sufficiently distant from the sea to preclude the possibility of in time drawing in salt water, and much softer than the well water in town, which was found to be in most cases seriously affected by house drainage or sea water.

The water, when pumped by hand from each of the six five-inch pipe wells of the system as put down, was clear, tasteless, and odorless. When pumped from all the wells collectively in large quantities, the water had a higher degree of color, comparatively speaking a little less than the Sudbury River water, and a slight odor of sulphuretted hydrogen, the latter quickly disappearing on exposure to the atmosphere.

The extreme porosity of the sand, permitting a free movement of the water through it, and the adaptability of the type of strainer used on the wells was demonstrated by pumping from a single well at the rate of two hundred and fifty gallons a minute.

Examinations for iron in the water, made at the time of a preliminary pumping trial (the quantity of iron in the earlier samples not having been determined), showed that the quantity found in the water after passing through the temporary pump and uncoated wrought-iron suction pipe was about twice as much as was found in water from the same well drawn directly from its top; and about

twenty-three times as much as was found in water taken from an observation well of $1\frac{1}{4}$-inch galvanized pipe in the same vicinity, the latter quantity being below the amount necessary for precipitation. The results of these examinations left a question as to how much influence, if any, the temporary uncoated suction pipe had on the quantity of iron found.

In consequence of the excellent filtering properties of the Provincetown sand, an idea was entertained that it might in time act in a beneficial manner in the vicinity of the wells, after long-continued pumping had removed a large quantity of water and created a better circulation. The existing conditions are such that the only natural movement of the ground water is when it runs out on the beach at low tide, giving the upper layers an opportunity to move first and most rapidly, while the lower layers have little or no opportunity to move from this cause, rendering them therefore somewhat stagnant.

That some beneficial action has taken place in the sand in the vicinity of the wells would seem to be indicated by the fact that from all of a number of test wells put down in 1895 under the direction of Mr. J. D. Adams, Superintendent and member of the Water Board, the water was reported to be good; that is, free from color, taste, and odor. One of these wells was sunk at the known location of a test well in 1892, from which water with both color and odor was obtained.

The possibility of applying artificial filtration to the water at some future time was considered when the works were built, but filtration was not deemed essential until the necessity became apparent.

During construction of the works especial care was taken throughout the entire system to protect the pipe coatings, and in asphalting cut ends as a precautionary measure; for with ordinary water, rust and tuberculation begin only too soon in spite of coatings. The high normal chlorine of this water, due to the location, and the presence of sulphuretted hydrogen, rendered the possibility of its having a special affinity for iron not at all improbable.

It is of interest to note that there was a marked falling off in the quantity of iron found in the water when the permanent works were put in operation, the yearly average up to 1896 not having reached the average obtained from samples taken during one month's pumping in 1892 with the temporary pump and suction pipe.

The possibility of concentration or sedimentation contributing to the increased effect of the iron in its laundry action suggests itself,

for there is ample opportunity for this to occur in the pipes at places where the water has a diminished velocity, not only in the mains and hydrant branches, but in the suction pipe between the wells and pump, where there is also some opportunity for oxidation to take place.

The Provincetown works were designed so that the water should be aerated by permitting it to pass through the atmosphere in a thin spray at the standpipe, which has a capacity of 460,000 gallons, before passing to consumers; primarily, for the purpose of removing any undesirable gas that might be present, but also with the idea of assisting oxidation of the iron in the water at a place where the sediment, if any, could be removed periodically. The occurrence of sedimentation was shown later by a sample taken at the bottom of the tank when being cleaned.

That the passage of the water through the reservoir where the conversion of the iron from the soluble to the insoluble form is assisted by aeration, had some effect in a practical way, would appear from the fact that for nearly two years the water was used satisfactorily in the large laundries in town, the proprietor of one in particular expressing a decided preference for it on account of its softness. At the end of this time, and while pumping direct to consumers during the cleaning of the tank, favorable comments concerning the lighter color of the water led to a continuance of the direct pumping for a period of ten days, which seems to have given a different effect in the laundries, as the first complaints from them were received at that time.

In this connection it may be mentioned that parties using the water for washing purposes state that during the process, the coloring matter imparted by the iron appears to lie upon the surface of the cloth in the form of sediment, giving white clothes a yellow or streaked look, which if noticed in season, can be easily removed by rubbing or rinsing.

Many interesting features concerning the ground water at Provincetown have been noticed. In a certain yard there are two wells not very far apart, from which two qualities of water are drawn; from one the water is preferred for culinary purposes, from the other the water is used almost exclusively for washing clothes.

In another case there are two wells driven in the sand beneath a house, only a few feet apart, but to different depths; one furnishes fresh water, and the other salt water.

DISCUSSION.

Mr. Hazen. The suggestion is advanced by Mr. Hawes that the iron in the Provincetown water may be due wholly or in part to the action of the water on the iron of the well points, collecting pipes, force main, etc., instead of coming from the soil. This idea naturally suggests itself, and while I am not personally familiar with the conditions at Provincetown, I am certain that this is not ordinarily the explanation of iron in ground water. When iron rusts in contact with water, the ordinary product is ferric hydrate, or, as it is commonly called, iron rust. This substance is insoluble in water. If it is carried in suspension it is at once apparent, and its appearance and results are in every way entirely different from those of the ferrous compounds found in solution in ground waters, and which are so objectionable. Mr. Hawes also mentions that particular care was used in constructing the system to completely coat the iron at every point so that the water could not come in contact with the metallic iron.

The conditions at Provincetown, as Mr. Hawes has described them, are very similiar to the conditions of the dunes of Holland. These dunes were originally almost, if not quite, islands; but the land back from them has been reclaimed by the construction of dikes along the rivers, while along the sea the dunes themselves serve to keep the ocean back. The poulders thus formed are often ten, twenty, and in some cases thirty feet lower than the level of the ocean, and are now cultivated.

The cities of Amsterdam, Haarlem, Leiden, and Hague are dependent upon ground water drawn from these dunes for their supplies. Unlike Provincetown, the water is collected in galleries constructed entirely of masonry or tiles, or in open canals, no iron whatever entering into their construction. Notwithstanding the method of collection, the water contains iron in large quantity, and would be just as troublesome as it actually is at Provincetown if it were used without treatment. As it is, this water is aerated and afterwards filtered through sand filters, of the ordinary construction, which remove every trace of the iron, and the water supplied is as good and pure as is supplied to any large city. At Columbus, Ohio, also, a collecting gallery is used, constructed entirely of masonry, but the

water drawn from it contains iron in solution in large quantity. Cases of this kind, I am sure, could be multiplied if search was made for them; and so while it may possibly happen that a water may exist which in itself has a tendency to dissolve metallic iron, and that such a water may take a little additional iron from the pipes through which it passes, I cannot believe that this is ever a leading or even important factor in causing the trouble experienced from iron in ground waters.

Mr. Hawes. The possibility of metallic iron from the pipes contributing to the quantity of iron found in the water is a question of much interest, and specific data which will aid in its determinination are valuable.

The promulgation of the idea should not, however, be credited to me, as it originated with another, and in connection with the Provincetown water, simply as a suggestion, but coming from excellent authority in matters pertaining to water analyses, is entitled to consideration.

In consequence of the absence of conclusive demonstration I have neither accepted nor rejected it, but have stated some facts which have a bearing in this particular case, for the purpose of affording as much light as possible upon what has remained a doubtful point.

It would, of course, be gratifying to know positively that the iron of the works had no influence upon the quantity found in water of this peculiar character. Mr. Clark states in his paper on the removal of iron from ground water, that the metallic iron of the coke and iron filings performed an important function in the process of filtering this water, which would indicate that the water has an affinity for metallic iron to a marked degree.

In comparing the quantity of iron in ground waters obtained from pipe wells with the quantity obtained from works supplied by masonry galleries, as a way of determining the question, the necessary knowledge of the connecting pipes, and places from which the samples are taken should not be overlooked, for otherwise such a comparison is not conclusive from either point of view. Samples taken, as in the majority of cases, from a faucet in the pumping station may have been in contact with the iron of the suction pipe, vacuum, pump, and air chambers and connecting pipes, which ordinarily exist with either mode of supply.

The works of Reading, Mass., may be cited as a single illustra-

tion: the supply is from a collecting gallery constructed entirely of masonry, but the water is obtained by the pump through 450 feet of iron suction pipe.

The all important question, in this case at least, is evidently, as to why the quantity of iron increases from year to year; for if the water can be used in the laundry satisfactorily until it attains a certain quantity of iron, the problem is one of keeping the quantity below that degree.

The removal of a large part or the whole by filtration offers a ready solution, but the determination of the controlling reasons for the increase in quantity and changes before and after the water enters the works, I believe to be of interest and value in arriving at an understanding of the true situation and applying a remedy.

In comparing results of analyses of the Provincetown water made in 1894 and published in the report of the Massachusetts State Board of Health for that year, which are the only ones available that show the amount of iron in samples collected the same day, one before and the other after the water had been aerated in its passage through the standpipe, and extending over any considerable period of time, it is noticed that on six out of the eight days when samples were taken simultaneously, the quantity of iron found in the water that had passed through the tank was less than was found in the samples collected at the pumping station, as follows: —

Iron, Parts per 100,000.

	Water from tap at Pumping Station.	Water from a faucet in town.
1894, April 10	.1300	.1100
" May 8	.0950	.1050
" June 12	.2340	.2000
" July 16	.3100	.3900
" Aug. 14	.2500	.1500
" Sept. 10	.2400	.2000
" Oct. 9	.3600	.2500
" Nov. 8	.4300	.2500
Average	.2561	.2069

During this time the water was being used in the large laundries in town, and no difficulty was mentioned by the proprietors until the following year.

THE IRON-REMOVAL PLANT AT READING, MASS.

BY LEWIS M. BANCROFT, SUPERINTENDENT.

The water-works of Reading were completed in 1891, with the late M. M. Tidd as engineer.

Water is pumped from a filter gallery near the Ipswich River, about three miles north of the village, to a covered standpipe, 30 feet in diameter and 100 feet high. The bottom of the gallery is 22 feet below the level of the meadow. The gallery is 2½ feet wide and 4 feet high inside, L-shaped, with a total length of about 240 feet. The walls are of rough field stone, like an ordinary culvert, under a street; the top is covered with flat stone laid in cement. About 75 feet of the gallery is parallel with and about 40 feet from the river; the remaining 165 feet extends away from the river at a right angle. The quantity of water obtained has been quite satisfactory, but the quality has not.

After the works had been in operation about three months, complaints of the taste and odor of the water were very frequent, also of the staining of white clothes when boiled in it. This was at first laid to the new pipes and the new paint on the inside of the standpipe, as the first complaints were heard soon after the standpipe had been painted inside. After emptying the standpipe and flushing the pipes, it was found that the cause of trouble must be looked for elsewhere. The State Board of Health in their report for 1891 state that the water contains iron in solution, which precipitates out as a reddish brown deposit on exposure to the air. Waters of this character often have a disagreeable odor, from carburetted and sulphuretted hydrogen. The amount of metallic iron in a sample taken Nov. 8, 1891, was 1.33 parts in 100,000, or 0.78 grains per gallon. In December, 1894, a sample contained 1.03 parts in 100,000. During the last four years the amount of iron has averaged as follows: 1893, 0.1251; 1894, 0.2942; 1895, 0.2275; 1896, 0.2475 parts in 100,000.

In February, 1893, Mr. Desmond FitzGerald, C. E., was engaged to investigate and devise some plan for removing the iron from the water. He made a very thorough and careful investigation, and made his report in February, 1894, with the following recommendations: —

First. Pump the water from the filter gallery into a covered reservoir built in two sections, each of which should hold 500,000 gallons.

Second. Aerate the water thoroughly on its way to this reservoir.

Third. Build invert to the reservoir with a steep inclination towards the drains, so that the sediment precipitated upon the bottom will scour out easily.

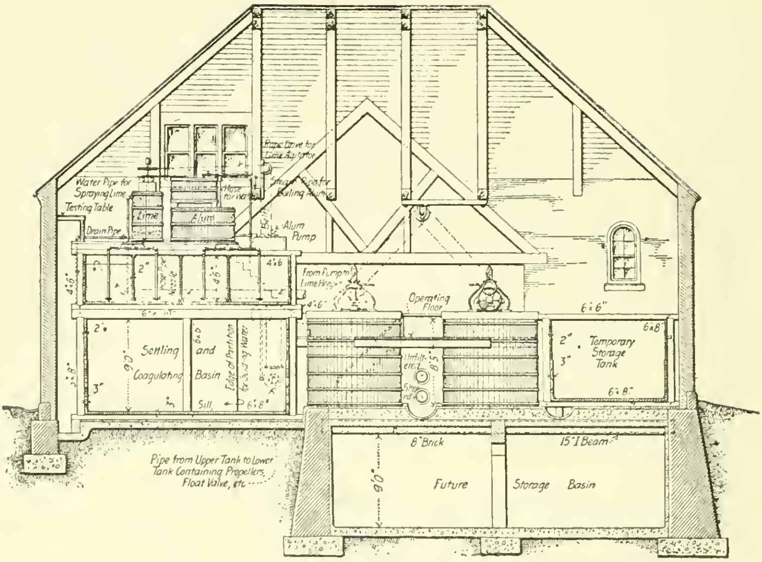
Fourth. Place this reservoir high enough to filter the water and return it to the present pumps. The water drawn from this reservoir can be filtered rapidly through any cheap form of filter which can be readily cleaned.

Fifth. After the plans are made, I should recommend you to put in the filters at once, and run them without the reservoir until the opening of the coming season.

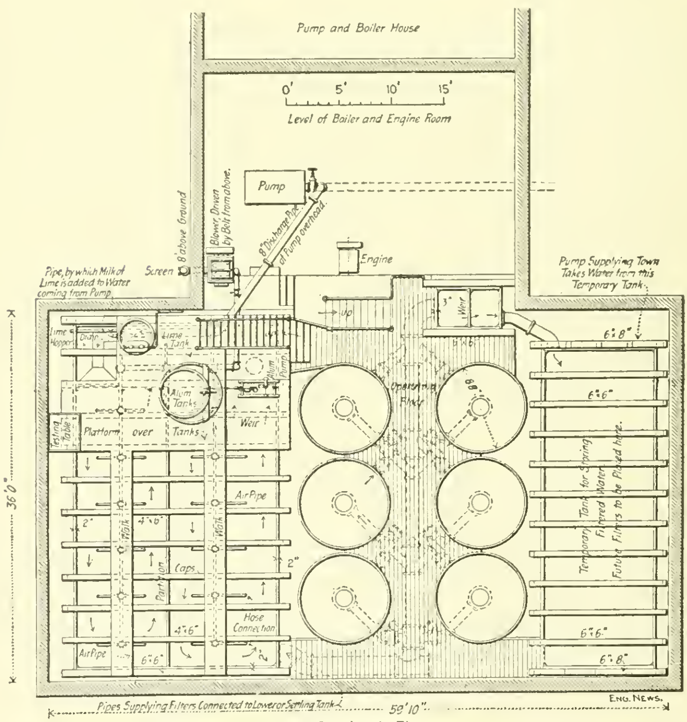
Sixth. The outlets or drains to the reservoir should be arranged so that the flocculent iron can be collected for use, if found necessary. I have found in my experiments, and it was suggested by Dr. Drown, that by adding some of this flocculent iron to the water, the precipitation of the iron is somewhat hastened.

Plans and specifications for a reservoir, as recommended by Mr. FitzGerald, were prepared by Mr. Frank L. Fuller, C. E., of Boston, and it was proposed by the Water Board to proceed at once with the work, but the voters of the town objected to the expenditure of so large a sum of money on what appeared to them an experiment. The State Board of Health were asked to approve Mr. FitzGerald's plans, or recommend some other plan. On Feb. 18, 1895, they made their report, with this advice: "With its present information, the Board advises the town of Reading to take measures to obtain its future supply as a part of the metropolitan water district, and abandon its present source when the new supply becomes available. In the meantime provisions should be made to improve the present supply by preventing the flooding of the meadow over the filter gallery, and it may be advisable to adopt, temporarily, some system of filtering the water rapidly through sand."

Early in 1895 measures were taken to prevent the flooding of the meadow by the purchase of the mill privilege and the construction of a low dike, and in August a contract was made with the Cumberland Manufacturing Company, of Boston, to put in a purification plant, which combined lime treatment, aeration, and rapid sand filtration,



Transverse Section.



Sectional Plan.

FIGS. 2 AND 3.—PLAN AND SECTION OF WATER PURIFICATION PLANT, READING, MASS.

through mechanical filters of the Warren type. This company had been studying the water for three years.

The water is taken from the existing suction pipe by a low-duty, compound, duplex Worthington pump, 6 x 9 x 11½ x 10, and delivered into the aerating basin, which is 33 x 19 x 4½ feet. There is a hopper at one end through which the water is delivered. At this point it is met by the descending supply of milk of lime, which is supplied from a tank, on top of which is a pan in which the lime is slaked. On receiving the lime it passes into the aerating basin proper, which is so divided by partitions as to cause the water to travel back and forth four times. The water during this passage is aerated by means of 23 1¼-inch nozzles, perforated with 6 $\frac{1}{16}$-inch holes. Air for this aeration is supplied by a No. ½ Wilbraham Baker blower through a 5-inch pipe at a pressure of 2½ pounds per square inch, as shown by a mercury gauge. This blower has a capacity of 150 cubic feet of air per minute. The iron is thus thoroughly oxidized, and the water, together with the suspended iron, passes over the last weir and through a 10-inch pipe at the outlet of which is an 8-bladed propeller of brass, so arranged as to revolve freely with the passage of the water. This, by means of two small bevel gears and an upright shaft, operates an alum pump, consisting of six hollow arms radiating from a chambered hub and bent in the direction of rotation. This pump revolves in a small tank containing a dilute standard solution of alum, and by its revolution each arm takes up a small amount of alum water, passes it into the hub and to the deflector, which sends it down into the water. Only two of these tubes are used, the other four being closed up.

The water has now reached the settling and coagulating basin, which is 33 x 19 x 9 feet, and is beneath the aerating basin and provided with partitions. The water remains about an hour in this basin and from there passes to the filters, which are 6 tanks 8 feet 8 inches in diameter and 8 feet 5 inches deep, and each have an area of 54 square feet. Each filter contains a bed of sand from Sebago Lake, Me., 2 feet in depth, supported by a perforated copper bottom. The agitator for cleaning this bed consists of a heavy rake containing 11 teeth 25 inches long, rotated by a system of gearing and capable of being driven into the bed by means of a screw mechanism; the current of water being reversed and flowing up through the sand, the entire bed is thoroughly scoured. Power for running this agitator and the blower is furnished by a 10 horse-power upright Lawrence engine.

The main, collecting the filtered water from the various filters, passes along between them to a weir, over which the water is compelled to pass and which controls the operation of the filters. From this weir the water passes to a clear water tank, 31 x 10½ x 8 feet, and from this tank flows to the pumps which supply the town.

This tank occupies a space which is intended for more filters. A storage tank for filtered water, 32 x 34 x 9 feet, is provided for underneath the filters, but has not been finished.

The alum solution is prepared in two tanks, one above the other, on top of the aerating basin. The alum is placed in the upper tank, and, by means of water and steam admitted, a concentrated solution is made. A small portion of this is drawn off into the lower and larger tank and mixed with the water until a standard five per cent solution of alum is formed. This solution is then fed into the small rectangular box in which revolves the alum pump.

The building which contains this plant is of brick, with slate roof, and adjoins the pumping station. Owing to the changeable character of the water, a strict watch is kept upon it, the incoming water is tested for iron, and the water both before and after aeration and after coagulation is tested, both for alkilinity and iron, and after filtration is tested for iron, lime, and alum. The engineer in charge has no difficulty in making his tests, and so regulates the amount of lime and alum as to prevent the use of an excess and enable the plant to properly handle the water.

In July and August, when the consumption of water is large, the filters were washed twice a day; but when the consumption is light they are washed once a day. We have found by a careful test that about four per cent of the water pumped is required for washing the filters. We use pure lime made from marble, which is procured from northern Vermont. The plant has been in operation since the first of July, and samples of the water, both filtered and unfiltered, have been analyzed by the State Board of Health twice a month, and the least amount of iron removed was 83.16 per cent, and in two cases 100 per cent was removed. The average amount of lime used per gallon of water is three grains, and of alum one and a half grains.

I am of the opinion that had the large settling basins, as recommended by Mr. FitzGerald, been built, these filters could be run with the use of but very little or no coagulant. The piping of the filters is so arranged that these can be added at any time.

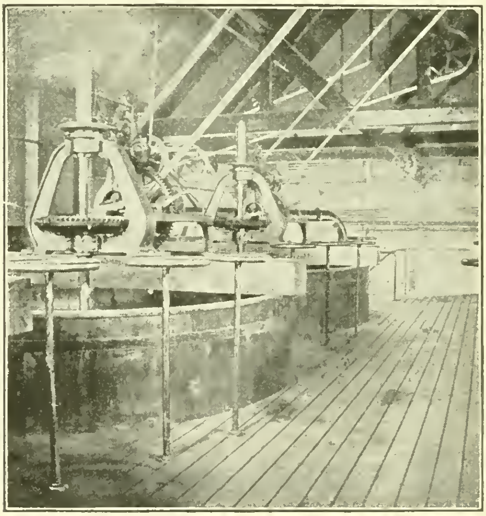
ANALYSES OF WATER FROM READING WATER-WORKS, MADE BY MASSACHUSETTS STATE BOARD OF HEALTH.

PARTS IN 100,000.

Date.		Appearance.			Residue on Evaporation.	Ammonia.		Chlorine.	Nitrogen as		Oxygen Consumed.	Hardness.	Iron.	Per cent of rem. of iron.	Remarks.
		Turbidity.	Sediment.	Color.		Free.	Albuminoid.		Nitrates.	Nitrites.					
July	27	Decided.	Cons. rusty.	Turbid 0.40	9.50	.0048	.0076	.53	.0050	.0000	.3420	3.6	.0850	–	Unfiltered.
"	27	None.	None.	0.13	15.50	.0058	.0056	.52	.0030	.0000	.1520	8.2	.0090	89.41	Filtered.
Aug.	10	Decided.	Considerable.	0.63	8.70	.0048	.0056	.54	.0000	.0001	.3635	2.6	.1400	–	Unfiltered.
"	10	Very slight.	None	0.30	14.50	.0040	.0046	–	.0000	0002	.2410	7.9	.0210	85.00	Filtered.
"	25	Decided.	Considerable.	0.60	7.40	.0070	.0064	.56	.0000	0000	.3542	2.5	.0950	–	Unfiltered.
"	25	None.	Very slight.	0.20	14.20	.0044	.0056	.52	.0020	.0010	.2010	8.0	.0030	96.84	Filtered
Sept.	8	Dist. from iron.	Cons. brown.	0.50	8.50	.0066	.0046	.62	.0030	.0030	.1725	2.6	.0950	–	Unfiltered.
"	8	None.	Very slight.	0.20	13.90	.0030	.0044	.61	.0030	.0018	.1725	7.3	.0160	83.16	Filtered.
"	21	Decided from iron.	Heavy rusty.	0.38	12.20	.0084	.0088	.56	·0050	.0000	.3160	3.9	.3350	–	Unfiltered.
"	21	None.	None.	0.10	18.00	.0048	.0062	.55	.0040	.0025	.2291	10.0	.0000	100.00	Filtered.
Oct.	6	Decided from iron.	Cons. rusty.	1.10	12.20	.0090	.0120	.56	.0030	.0001	.4068	4.0	.3800	–	Unfiltered.
"	6	Very slight.	None.	0.09	20.40	.0010	.0086	.57	.0030	.0035	.2923	11.3	.0100	97.37	Filtered.
"	21	Dec'd m'ky and rusty floc.	Heavy rusty.	After set. 0.10	14.90	.0104	.0106	.53	.0050	.0000	.4895	5.2	.5600	–	Unfiltered.
"	21	None.	None.	0.08	24.80	.0026	.0078	.57	.0050	.0060	.2409	15.5	.0000	100.00	Filtered.
Nov.	10	Decided.	Considerable.	Turbid 0.50	15.40	.0110	.0098	·55	.0050	.0000	.4758	5.8	5250	–	Unfiltered.
"	10	None.	None.	0.10	26.80	.0032	.0082	.54	.0050	.0015	.2457	14.7	.0360	93.14	Filtered.
"	24	Dec'd milky and floc.	Heavy rusty.	0.50	15.10	.0102	.0090	.57	.0080	.0001	4485	5.0	.4800	–	Unfiltered.
"	24	None.	None. [yellow.	0.12	24.60	.0022	.0082	.61	.0050	.0010	.2457	15.0	.0010	99.79	Filtered.
Dec.	8	Dec'd floc. of iron.	Heavy, light	After prc. 0.40	16.76	.0092	.0120	.48	.0070	.0001	.5694	6.3	.4450	–	Unfiltered.
"	8	None.	None.	0.10	20.60	.0016	.0078	.56	.0050	.0010	.2317	14.5	.0020	99.55	Filtered.
"	20	Dec'd milky and floc.	Cons. rusty.	0.50	15.00	.0104	.0092	.55	.0080	.0000	.4920	6.0	.4850	–	Unfiltered.
"	20	None.	None.	0.10	22.80	.0022	.0068	.57	.0100	.0010	.2400	13.5	.0050	98.97	Filtered.

DISCUSSION.

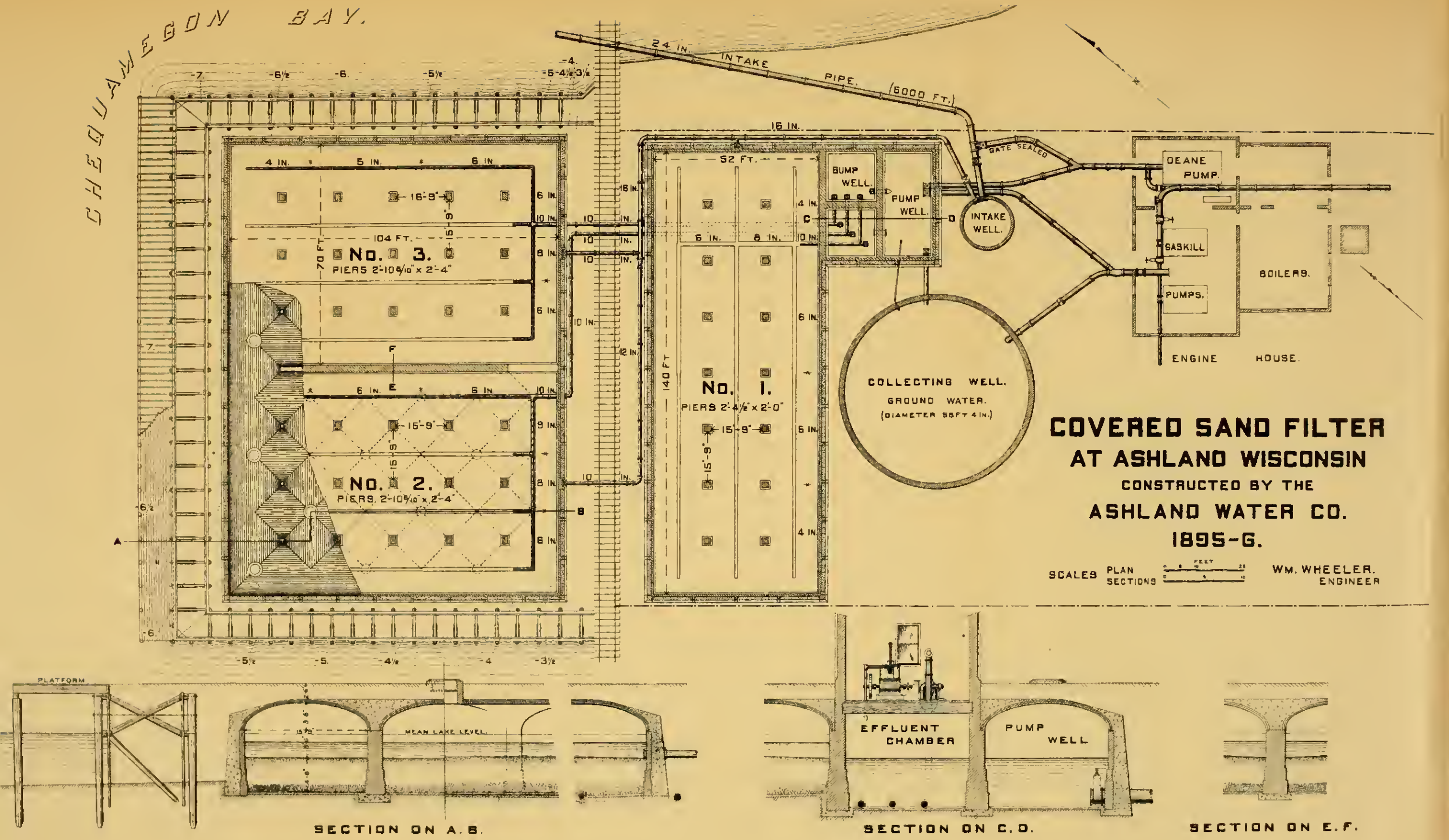
Mr. Nye. It may be of interest to the members to know that in the course of the operation most of the lime, as well as the alum that is coagulated in contact with it, is caught in the settling basin; and I am informed by the engineer of the plant that at one time, after something like ten weeks' operation, there was about six feet of sludge in the bottom of the basin, which was removed and run off into the river. The average amount, I think, is about a foot.



S.

ing sub-
ie degree
rly shore
Superior,
iles, and
d to six
ng about
obliquely
ive miles
known as
al break-
sland and
alf miles
lf a mile
he south-
le in both

e bay, in-
somewhat
ernment),
ch, begin-
, one and
, extends
ite shore.
n area of
s draining
nposed of
r streams
are miles
shets and


CHEQUAMEGON BAY.
24 IN. INTAKE PIPE. (6000 FT.)
GATE SEALED
SUMP WELL.
PUMP WELL.
INTAKE WELL.
DEANE PUMP.
GASKILL
PUMPS.
BOILERS.
ENGINE HOUSE.
No. 3.
PIERS 2'-10 8/10" x 2'-4"
104 FT.
70 FT.
No. 2.
PIERS 2'-10 8/10" x 2'-4"
No. 1.
PIERS 2'-4½" x 2'-0"
52 FT.
140 FT.
COLLECTING WELL.
GROUND WATER.
(DIAMETER 55 FT 4 IN.)
COVERED SAND FILTER
AT ASHLAND WISCONSIN
CONSTRUCTED BY THE
ASHLAND WATER CO.
1895-6.
SCALES PLAN SECTIONS
WM. WHEELER. ENGINEER
PLATFORM
MEAN LAKE LEVEL
SECTION ON A.B.
EFFLUENT CHAMBER
PUMP WELL
SECTION ON C.D.
SECTION ON E.F.

COVERED SAND FILTER AT ASHLAND, WIS.

BY WILLIAM WHEELER, C. E., BOSTON.

[*Read March* 10, 1897.]

The city of Ashland, Wis., is in latitude 46° 34′ N., being substantially the same as that of Quebec, Canada, and about one degree farther north than Montreal. It is situated upon the southerly shore and near the head of Chequamegon Bay, an arm of Lake Superior, whose length from southwest to northeast is about twelve miles, and whose width ranges from two and a half miles at the head to six miles in the widest part near its mouth, its total area being about fifty-six square miles. Extending nearly two thirds the way obliquely across the mouth of the bay is an insular sand spit about five miles long and from three hundred to fifteen hundred feet wide, known as Long Island or Chequamegon Point, which forms a natural breakwater for the bay. Between the northwesterly end of the island and the mainland lies the main channel, about two and a half miles wide, while the southeasterly end is about a quarter to half a mile distant from the point of the mainland on the south. The southeasterly channel was naturally shoal, and somewhat variable in both depth and width.

The natural circulation of the water at the head of the bay, including the harbor and anchorage of Ashland, was somewhat impeded by the construction (by the United States Government), from 1890 to 1892, of a breakwater 7,350 feet long, which, beginning about three thousand feet from the Ashland shore, one and three fourths miles northeast from the pumping station, extends northwesterly to within two and a half miles of the opposite shore. That portion of the bay thus partially impounded has an area of twelve square miles, and into it discharge creeks and rivers draining about one hundred and fifty square miles of watershed composed of red clay and alluvium. Farther down the bay enter other streams draining some two hundred and fifty to three hundred square miles more of similar territory. During the spring thaws and freshets and

in times of heavy rainfall these streams are heavily charged with red clay and mud which impart their characteristic color and substance to the waters of nearly the entire bay.

In 1894 the gap at the southeasterly end of Chequamegon Point was closed up by the government for the purpose of extending and strengthening the protection which the island afforded to the land-locked waters of the bay. The closing of this gap is believed by those who have studied the problem to have still further diminished or checked the natural circulation of water in the bay by compelling the inflowing current moving westerly along the northerly shore, and which formerly found its outflow through the said gap, to return upon itself within the bay, and find its present outflow into the main lake along the opposite side of the channel by which it enters.

The city of Ashland was incorporated in 1887. Its territory comprised a part of that previously contained in the town of Ashland and some "Additions" adjacent thereto, leaving unincorporated a portion only of the original town.

By the United States census of 1880 the town of Ashland as then constituted had a population of 951. By the United States census of 1890 the population of the city of Ashland was 9,956, and that of the town outside of the city limits 1,507, making the total population of the territory under consideration 11,463. The present population of this territory is estimated at about 15,000.

The water works were constructed in 1883, and water first introduced early in 1884 by the Ashland Water Company. The works were built under the direction and control of the Holly Manufacturing Company of Lockport, N. Y., and the method of supply is the well-known Holly system of direct and continuous pumping according to the current demands of the service. The original pumping plant comprised two 1,500,000-gallon Gaskill pumping engines. The pumping station is located near the easterly verge of the populated district upon the water front, and the supply was first obtained directly from the bay through a 16-inch wrought-iron intake pipe extending about two thousand feet out from the shore.

In 1889 a new intake of 24-inch cast-iron pipe was constructed. It was laid in a dredged channel, and extends about five thousand feet out into the bay to a contour about twenty-two feet below mean

water. It deflects somewhat to the eastward and away from the harbor in front of the city, so that its outer end extends to within about one mile of the farther end of the breakwater.

In 1888 sewers were first constructed by the city in some of the principal streets, and have since been gradually extended. They are upon the separate system, and discharge directly into the bay at three different points along the water front, all being west or toward the head of the bay from the pumping station.

In 1891 the principal stock holdings in the company changed hands, and the new interests, so created, resulted in a complete change in its management. Large additions to the distribution system were made coincident with extensions of the fire service ordered by the city, and these were followed by more sewers, and by an increase in the pumpage, to provide for which a 4,000,000-gallon Deane pumping engine was installed in 1894.

The consumption of water in 1891, as determined from the imperfect records kept at that time, averaged from 800,000 to 1,000,000 gallons per day. In 1895–6 (March 1 to March 1), it had increased to an average of 1,343,219 gallons, and fell back in 1896–7 (under some increase in the use of meters) to 1,340,032 gallons per day, of which 250,000 gallons and upwards daily are of ground water supplied by the collecting well, to be described farther on.

In 1893 and 1894, Ashland, in common with many other communities in northern Wisconsin and Michigan, experienced an epidemic, variously termed by physicians "winter cholera," "typhoid fever," "typhoid malaria," etc. It appeared in small communities having no aqueduct system of supply, — in cities whose municipal water sources were open to the suspicion of contamination by sewage, in others where some degree of pollution was certain, and in still others where the purity of the water supply was unquestioned. Among physicians and people there was a division of opinion as to the identity of the disease and the chief agencies of its transmission, but in the minds of some of the leading authorities in the State, familiar with the symptoms of the disease and the conditions under which it appeared, it was thought not to be true *typhus*, and that other causes than impure water contributed to its wide distribution. The sudden appearance of the epidemic throughout so wide an extent of country, and its equally sudden abatement, seemed to indicate that in some

cases, at least, public water supplies were charged with a larger share of responsibility therefor than was their due.

At Ashland, however, the menace to the purity of the water supply which was created by the construction of the city sewers in 1888, supplemented by the alarm to which the epidemic gave rise, led the company to devise measures that would not only satisfy the standards of its own advisers, but also remove any just occasion for alarm upon the part of its patrons and the municipal authorities. To this end, new sources of supply were considered. The open lake was at so great a distance, — ten miles in an air line, — as to make the cost of going there prohibitive. The extension of the intake beyond the breakwater would still afford a supply from the bay only, — subject to discoloration during freshet stages of the streams contributing thereto, and to such modified chances of contamination as would ensue from getting somewhat farther away from the sewers of Ashland, but at the same time nearer to the sewers (present or prospective) of the town of Washburn situated about five miles away on the other side of the bay.

Certain springs west of the town of Ashland, about four miles from the pumping station, might have been utilized by abandoning the present station altogether, and readjusting the entire arterial system to a new heart of the works, and while the necessary consent of the city government to the substitution of a somewhat hard spring water for the softer water of the bay might have been forthcoming, the cost thereof was again practically prohibitive.

Ground water is found along the water front of the city of Ashland at a depth of from thirty to fifty feet below the lake surface. The water-bearing stratum at the pumping station is found at a depth of about thirty feet below the surface of the lake. It is about thirty feet in thickness, rests upon red sandstone, and is overlaid by a hard, compact, and impervious pan of red clay mixed with gravel and some bowlders. The thickness of the superimposed hard-pan increases back from the shore by reason of the increased elevation of the ground surface. The static head or pressure of this ground water, along the vicinity of the shore, is about fourteen feet above the level of the lake, and the quantity and quality of the free outflow obtained at lower levels, from some tubular test wells sunk early in 1894, afforded the prospect of obtaining a partial supply at least, whose value would be commensurate with its cost, even if filtration of the bay water

should ultimately be found to be necessary. During the last half of that year, therefore, the company constructed a large circular collecting well, 58 feet 4 inches in diameter, and extending down entirely through the hard-pan to the water-bearing stratum 32.50 feet below the lake level and 39.00 feet below the finished ground line around it. This well now overflows at 4.50 feet above the lake, and contains in store 20,000 gallons for each foot of its depth below the overflow, 37 feet, or a total of about 740,000 gallons.

Ten 6-inch tubular wells were also sunk upon the pumping station premises, all within an area, 280 feet square. These are connected up with the collecting well by pipes laid at about the level of the lake, and draft by siphonage whenever the water in the main well is drawn below that level.

The collecting well flows freely, and yields or overflows at the rate of 252,000 gallons daily at 4.50 feet above the lake level. At the level of the lake, the free flow amounts to about 325,000 gallons daily, while by drafting down to ten feet below the lake (the greatest depth practicable with the pumping machinery in its present position) the normal yield or flow amounts to about 450,000 gallons per day.

The original plan for a supply of ground water contemplated a possible extension of the tubular well system along the water front of the city outside the premises of the company to such distance as should be found needful to procure the requisite quantity. Meanwhile, the experience of the writer, with various systems of mechanical filtration of public water supplies at other places, and a study of the possibilities of the slower process of sand filtration as illustrated by the open filter at Lawrence, Mass., and also in European practice, so well described by Mr. Hazen in his work on "Filtration of Public Water Supplies," which appeared early in 1895, and by the investigations and reports of others, led to the ultimate adoption of slow filtration through sand as the best solution of the problem.

The policy of the Water Company upon this question was submitted by the writer in July, 1895, to a committee of citizens and members of the city government, to whom the matter at issue had been referred for consideration and report. The committee reported favorably thereon to the City Council, with resolutions for carrying its recommendations into effect, and upon the 5th of August the report was adopted and the resolutions were passed by the Council and accepted in behalf of the company, which was thereby committed

to the construction of an earth and masonry covered filter for the filtration of the entire supply of bay water to be furnished by it.*

The pumping station lot fronts one hundred and fifty feet upon the bay, between a public street on the west (Twelfth Avenue east) and private owners on the east. The land area between the engine house and the natural shore line was not only insufficient for the filter but was already occupied by the collecting well and other appurtenances of the station. Across the extension of the lot into the bay, and at a distance of fifty to one hundred and twenty feet from the shore, is a siding of the Chicago & Northwestern Railroad, a right of way for which, sixteen feet wide, had been granted by the Water Company in 1886.

The most practicable location for the filter at or near the pumping station was clearly that contained between the extension of the side lines of the company's property into the bay, for which purpose the gradual slope of the bottom, the nature of its material, and the favorable opportunity afforded for placing the works below the level of the lake to operate by gravity, made the advantages of the site apparent.

The net area of the filtration surface is approximately half an acre, contained in three compartments, numbered 1, 2 and 3, respectively. No. 1 is on the land side of the railroad track and occupies a portion of the margin of the bay, naturally shoal, that had been filled up with slabs and earth before this work was undertaken. It is one hundred and forty feet long by fifty-two feet wide inside, and contains two rows of piers, seven in each row, for the support of the covering arches, the horizontal section of each pier being 4.75 square feet. Compartments 2 and 3 are entirely outside the railroad track, where the mean depth of the water was from four to seven feet. Each of these compartments is one hundred and four feet long by seventy feet wide inside, and contains three rows of piers, having five in

---

* Extract from report of joint committee above referred to: —

"The first item in importance is the question of pure water. The company proposes to adopt the filter bed system, largely used in European cities, where the source of water supply has been contaminated by the sewage from populations numbering into the millions. The result, as published in Hazen's work on Filtration, would indicate that the system of filtration there used removes both physical impurities and bacteria from the water. . . .

"The committee submits herewith a resolution which embodies the substance of our negotiations with the Water Company representatives, and which, if adopted by the Council and accepted by the Water Company, will constitute a contract, and will settle all differences now existing."

each row, for the support of the covering arches, the horizontal section of each pier being 4.433 square feet.

The entire water area occupied by the filter was first enclosed on its three water sides with a permanent coffer-dam or bulkhead, for the double purpose of excluding the water of the lake during the construction of the works, and for their permanent protection thereafter. Those portions of the dam along the two sides of the property were placed just outside the property lines with the consent of the adjacent owners, thus leaving the full width between the lot lines for the filter itself. The dam consists of two rows of round piling driven from seven to eight feet apart in the rows, the piles in the two rows being opposite each other, and the rows ten feet apart on centres along the two sides of the work, and twelve feet apart in that portion against the outer end.

The piles are driven from six to eight feet into the hard-pan bottom, and cut off at a uniform height of about five and a half feet above mean water. At the water level, and also at the top of each row, continuous eight-inch by eight-inch stringers or rangers are notched into the faces of the piles that are toward each other, and against the rangers, lines of three-inch sheeting are driven. The outer row of piling is braced at each pile by shores driven between the rows, and drawn over and bolted to each pile through the stringer placed at the water line. The two rows are securely tied or trussed to each other at each pile by a panel of vertical cross braces and tie-bolt placed above the water level, as indicated in the accompanying drawing, and fender piles driven at the outside corners. The space between the two lines of sheeting was then filled with material that had been excavated from the collecting well the year before, and the water in the enclosed area pumped out.

The grades of the principal features of the works, referred to mean water of the bay, are as follows: —

The bottom of main filter walls, and of partition between compartments 2 and 3, are on hard-pan, at 7.75 feet below mean water.

The piers supporting the covering arches rest on concrete foundations, four feet square and one foot thick, — bottom of foundations being 8.75 feet below mean water.

The finished floor of filter compartments along walls, partition, and pier lines is 7.50 feet below mean water. Along the channels for the collecting drains the floor is made lower, — according to the varying

diameters of the pipes, to bring the tops of the pipes to the uniform height of 7.50 feet below mean water.

The walls and partitions of the effluent chamber, pump well, and sump well are on concrete foundations nine inches thick, the bottom of which is at 10.50 feet below mean water, while their floors are at an average grade 9.50 feet below.

The outside walls are three feet thick at the bottom and two feet at the springing line of the covering arches. They are of composite construction, consisting of a brick facing and a backing of cement concrete. The facing is twelve inches (three brick courses) thick in the lower part, and eight inches (two courses) in the upper. At intervals of twelve feet, against the back side of the facing, buttresses of the same material, two courses thick, were built up and bonded therewith, — the depth and batter of the buttresses being the same as of the concrete backing filled into the spaces between them to complete the wall.

The brick work is laid in Portland cement mortar. All concrete in the work is also of Portland cement, mixed with bank sand and beach gravel or pebbles, in the proportions of one, two and a half, and five parts, respectively.

All piers and partition walls are of brick, laid in Portland cement mortar, all mortar used being of two parts of cement to three of sand.

The vertical joints between the faces of all the walls and piers and the filter bed are broken by two horizontal ledges or offsets of two inches each in width at 1.75 and 3.25 feet respectively above the floor level of the filter compartments, both ledges being within the limits of the sand stratum.

The piers are spaced 15.75 feet apart in the clear, each way, from each other and from the adjacent walls in each of the three filter compartments, which, with the pump well, are covered by groined elliptic arches of 15.75 feet span and 3.50 feet rise. The arch rings are about five inches thick, consisting of two courses of bricks laid flatwise in Portland cement mortar. The spandrels of the arches and the spaces over the piers and adjacent walls are filled and covered with a backing of Portland cement concrete up to a general level of four feet above the spring of the arches, but sloping down to a height of two feet only above the springing line at the rear of the outside walls.

The arches covering compartments 2 and 3 were the first to be turned, centres for which were provided for their full area at the outset. When these arches and their concrete backing were completed the centres were removed, and enough material taken from them for centering compartment 1 and the pump well.

The bricks in the arches are laid in uniform horizontal courses, and cut or mitred to fit the angles of their intersections, except in a few courses next the springing lines, and also at and near the crowns where the corresponding courses of the intersecting arches are neatly bonded with or into each other without cutting.

At the alternate intersections of the arches manholes to the number of twelve in each compartment afford access and admit light to the vaulted spaces below, during the process of cleaning and replenishing the filter beds.

Upon the concrete backing which overlays the covering arches, and between the main walls and the coffer-dam which enclose the work, the earth is backfilled and neatly graded and seeded. The total thickness of the earth covering is two feet over the main part of the filter, or 6.50 feet above mean water, sloping down to 5.50 feet above mean water at the outer face of the coffer-dam.

The piers in compartment 1 carry a permanent load computed at 23,985 pounds per square foot of horizontal section, and those in Nos. 2 and 3, 25,460 pounds per square foot.* This load was temporarily increased, while the work was still new, to about fourteen and a half tons per square foot, in the case of two piers, by inadvertence on the part of some of the laborers, in piling a quantity of Portland cement in barrels upon the earth filling over them. No injury resulted therefrom, nor was any weakness disclosed thereby.

The effluent chamber and sump well are covered by a brick house containing the gate stands and hand wheels for controlling the flow from the various compartments, and an 8-inch centrifugal pump with Westinghouse engine for pumping out any desired compartment through the sump well.

---

* The weights of materials allowed in computing the loads on piers, including water of absorption, are as follows: brick work, 130 pounds per cubic foot; concrete, 160 pounds per cubic foot; earth covering, 115 pounds per cubic foot. The snowfall at Ashland is large, and an allowance for its accumulation upon the earth covering of the filter, to an amount equivalent to four inches in depth of water, would add to the load on the piers in compartment 1, 1,409 pounds per square foot, and in compartments 2 and 3, 1,497 pounds per square foot.

The bottoms of the filter compartments, effluent chamber, and pump well are floored with Portland cement concrete three inches thick. Along the lines of the collecting drains the depth of the concrete flooring is increased, and channels — half-hexagons in section — are formed therein to receive the drains. These drains are of vitrified sewer pipes in two-foot lengths, ranging in diameter from four inches at the head of each lateral to ten inches at the main outlet pipe, by which each compartment is connected with the effluent chamber.

The depths of the channels in which the collecting pipes are laid are half the external diameter of the bells of the pipes. A line of laterals extends along the centre of each colonnade in the direction of the greatest dimension of each compartment. For about one third of their length at their upper ends the laterals are of 4-inch pipe, enlarged to 5 inches for the middle third, and to 6 inches for the lower third, at which size they connect with the transverse collecting drains of 8-inch and 9-inch pipes leading to the 10-inch cast iron effluent pipe.

The raw water is supplied to each compartment through a 10-inch cast iron pipe branching from a 16-inch main which leads from the intake well into which the water is received from the bay.

The sand beds proper have a maximum thickness of about four feet. They are supported upon three layers of selected gravel stones of graduated sizes of grain for subdrainage. Of these the first or lower stratum of pebbles has a thickness of nine inches at and along the lines of the drains, and six inches midway between them, and next the walls. The second and third layers from the bottom are about two inches and an inch and a half respectively in thickness throughout, making the full depth of the beds five feet at the drains and four feet nine inches midway between them.

The gravel comprising the three strata which support the sand beds (together with that for concrete) was brought from the beach on the north shore of Lake Superior, near Two Harbors, Minn., a distance of about eighty miles, by water transportation. It cost by contract per cubic yard on the dock at Ashland, $1.80 in the fall of 1895, and $1.50 in August, 1896. This material ranged in size of grains from about 0.50 m. m. in diameter to stones two inches across in their greatest dimension. It was passed over two screens, whereby it was separated into the three desired grades. Of these the coarser — used for the bottom layer — is such as did not pass

through a screen having two meshes per lineal inch. That used for the second layer consists of such as passed through the screen of two meshes but not through one of four meshes per inch, while the finer grade upon which the sand rests is of the portion that passed through the screen of four meshes per inch.

The sand used for the filter beds in compartments 2 and 3 was drafted through the suction pipe of an 8-inch centrifugal pump from the bottom of the bay, just inside Chequamegon Point, and was delivered on the dock at Ashland in the fall of 1895 at sixty-five cents per cubic yard by contract.* That used in making the filter bed in No. 1, and in replenishing Nos. 2 and 3, was obtained from the beach at Big Bay, Madeline Island, about twenty-four miles from Ashland by water, and was delivered through manholes into the compartments (but not placed) in August, 1896, at ninety cents per cubic yard by contract.

These sands are similar in appearance and character. They are of fine but exceedingly uniform size of grain, that of 1895 from Chequamegon Bay having an "effective size" of 0.27 m. m., with a "uniformity coefficient" of 1.9, while that of 1896 from Madeline Island has an "effective size" of .40 m. m., and a "uniformity coefficient" of 1.6, according to the standard of measurement adopted by the Massachusetts State Board of Health in the Lawrence Filtration Experiments.† The sand from Chequamegon Bay contained a few

* Mr. A. H. Salisbury, Superintendent of the Lawrence Water Works, informs me (March, 1897) that it costs sixty-eight cents per cubic yard to *wash* the sand removed from the Lawrence filter, in the process of cleaning, not including the cost of replacing it on the filter bed. — W. W.

† Analyses, by the writer, of the two varieties of sand actually used in the construction and replenishing of the Ashland Filter beds, show the following results, to which are subjoined, for comparison, like analyses of single samples of two grades of bank sand (new) used in the open filter of the Lawrence Water Works, and of a sample of old sand that had been washed preparatory to replacing it on the filter bed: —

Samples Analyzed.	Effective Size.	Uniformity Coefficient.
Ashland sand, Chequamegon Bay, October, 1895	.27 m. m.	1.9
" " Madeline Island, August, 1896	.40 m. m.	1.6
Lawrence, new sand, No. 50, March, 1897	.21 m. m.	4.4
" " " " 70, " 1897	.30 m. m.	5.1
" washed sand, " 1897	.40 m. m.	2.5

Analyses of four samples of sands, available for use in the Ashland Filter, made by Mr. Allen Hazen, prior to the construction of the work gave the following results: —

Samples analyzed.	Effective Size.	Uniformity Coefficient.
Fine Bank sand	.26 m. m.	1.6
Coarse Bank sand	.33 m. m.	1.6
Lake sand, locality not reported	.30 m. m.	1.5
Beach sand, Bayfield shore	.38 m. m.	1.6

gravel stones, which were separated by screening. It was procured during the latter part of October, 1895, and was discharged from scows by pumping into bins on the dock. When the two compartments first completed — Nos. 2 and 3 — were ready for their sand beds in December, 1895, and January, 1896, the sand was frozen solid. It therefore had to be thawed and dried by artificial heat before it could be screened or used. For this purpose a multi-tubular furnace was improvised from six 12-foot lengths of 16-inch water pipe arranged in a battery of three horizontal flues, each 24 feet long, and placed 4.50 feet apart on centres, and parallel to each other. A 12-foot length of 8-inch water pipe set up and connected vertically at the spigot end of each flue afforded the draft necessary to maintain combustion in the flues, fuel for which was cheaply and conveniently furnished in the form of slabs. The sand to be heated was piled upon the horizontal pipes and around the vertical ones to the depth of three or four feet in a large bin enclosing all but the bell ends, through which the fires were fed. The sand and gravel used for mortar and concrete during freezing weather were also heated in the same manner.

The impervious character of the hard-pan, on which the filter is built, and somewhat of the thoroughness with which the coffer-dam and the masonry were constructed are indicated by the fact that the entire amount of seepage into the whole area of the works (all of which drained into the sump well, at a depth of about ten feet below the level of the bay) amounted in ninety-six hours to about one thousand eight hundred and sixty gallons, being at the rate of about one gallon in three minutes.

The entire works, with the exception of the filter bed in compartment No. 1, were substantially completed, and the gate in the only connection between the raw water intake and the pumps was closed Feb. 5, 1896,* just six months after the work was determined upon, within which time all plans and specifications had also to be prepared therefor. Thenceforth the entire supply has been filtered with the exception of the ground water overflowing from the collecting well, as above described. The above date is believed to mark the completion and beginning of operation of the first masonry covered filter of its type in America.

---

*At the suggestion of the writer, this gate was sealed Feb. 10, 1896, in the presence of the City Physician and the Superintendent, who reported March 2, 1897, that the seal "has never been broken or disturbed since."

The works were designed by the writer, and constructed by day labor under the personal oversight and direction of Mr. Sam Wheeler, the superintendent of the company.

The discharge of the overflow of ground water into the effluent chamber was continued until July 9, 1896, when (in order to permit the taking of samples of the filtered water, unaffected by the ground water, and without temporarily increasing the rate of filtration by its exclusion from the supply during such taking) it was permanently turned into the filtered water pump well.

Compartment No. 1 was provided with its filter bed in August, 1896, Nos. 2 and 3 only having been in service up to that time. The bed in No. 1 was completed and placed in operation Sept. 1, 1896. From Sept. 2 to 8, sixteen inches of sand were added to the bed in No. 2, of which about 11.50 inches represented the sum of the settlement that had taken place in the original bed, and the amount removed in the eleven cleanings thereof since Feb. 5, while the balance, 4.50 inches, was an addition required to bring the bed up to its full standard depth. No. 2 was again placed in operation Sept. 8, after which, — Sept. 9 to 13, — No. 3 (which likewise had been cleaned eleven times since February) was replenished and added to in the same manner, and placed in operation again on the last named date. Since then, all of the compartments having been in constant service, except when being cleaned, the cleanings have been much less frequent than before, as will be seen by reference to the accompanying tabulations of the operation of the filter, No. 1 having been cleaned three times, and Nos. 2 and 3 only two times each, from Sept. 13, 1896, to March 1, 1897. The greater frequency of cleaning previously required was doubtless chiefly occasioned by the smaller area of filtration then in use, and by the greater turbidity of the water during the spring freshets, but it is believed to have been materially affected also by the fact that several dredges were at work at the ore docks near the station during the summer, and the excavated material conveyed in scows over the outer end of the intake, and dumped into the bay near the breakwater.

The cost of the completed work as made up and classified from the books of the Treasurer and the notes of the Superintendent is summarized as follows : —

COVERED SAND FILTER AT ASHLAND, WIS.

Summary of Cost of Construction.

Coffer-Dam:		
470 lineal feet, approximately, exclusive of earth filling		$1.720 05
Excavation:		
6,943 cubic yards, used in coffer-dam, over arches, behind side walls, under railroad, and wasted (of which 700 cubic yards were handled twice).		3,233 15
Handling Water		493 00
Brick Masonry:		
340,400 bricks laid in side and partition walls .	$6.236 89	
45,000 bricks in piers	826 75	
349,550 bricks in covering arches (and some in backing)	6,755 23	
37 manholes, including iron frames, covers, and setting in brick work	724 31	
		14,543 18
Centres for Groined Covering Arches:		
Materials, erection and removal		1,156 59
House over Effluent Chamber and Sump Well .		626 79
Concrete:		
1,000 cubic yards, in place		5.976 57
Collecting Pipes:		
Vitrified pipe, laid	$116 34	
Cast iron pipe, specials, and valves, laid . .	639 14	
		755 48
Supplying Pipes:		
Cast iron pipe, specials, and valves, laid . .		725 46
Pipe Connections:		
Between pump well and sump well, effluent chamber, collecting well, centrifugal pump and pumping engines, cast-iron pipe, specials, and valves, laid		728 70
Filter Beds:		
880 cubic yards gravel in three lower strata . .	$1,949 30	
3,335 cubic yards sand in upper stratum . .	4,201 40	
		6,150 70
Sundries, not otherwise classified		2,267 95
Engineering and Superintendence		1.800 00
Total cost		$40,177 62

With the railroad track out of the way and the entire filtration area of one half acre constructed in one compartment, the reduction in cost consequent thereon would have been about $2,866.73.

The cost of the filter was much increased also by the inclemencies of the weather during the months of November and December, 1895, and January, 1896, in which all the masonry of compartment No. 1 and of the effluent chamber, sump well, and pump well, and the sand bed in compartments 2 and 3 were constructed. A careful consideration and estimate of the additional cost due to working in cold weather, short days and night work, indicate that the extra expense occasioned thereby was not less than $2,500.00.

The sum of these ($5,366.73) deducted from the actual cost ($40,-177.62) leaves as the estimated normal cost at Ashland of a filter of this type of one half acre in one compartment (including effluent chamber, pump well, sump well, piping, and housing), $34,810.89.

In localities where good building stone and suitable gravel and sand are near at hand, this cost should be reduced from ten to fifteen per cent.

The course of procedure in scraping or cleaning one of the filter beds is as follows: —

The need of cleaning is indicated by the head under which filtration takes place, which is shown approximately by the difference in level at which the water stands on the bed and in the effluent chamber and pump well, the gate in the effluent pipe being wide open. Under the present practice, cleaning is deferred until the gradual increase in head incident to the arrest of foreign matter on and in the upper part of the bed causes the water in the effluent chamber to fall from six inches to one foot below the top of said bed, indicating that the maximum head for the compartment to be cleaned is from three to three and one half feet.

On the day before cleaning, the raw water supplied to this compartment is stopped and the water stored therein continues to drain off through the sand into the effluent chamber until it stands about a foot below the top of the bed — this condition being usually reached by the following morning, — when it is ready for cleaning.

The tool commonly used for scraping is a two-edged wooden scraper or hoe, the blade of which, made from a $\frac{7}{8}$-inch board, is about fifteen inches long by six inches wide, with a handle joined perpendicularly thereto at its centre. The two cutting edges are bevelled at an angle of about forty-five degrees.

The sand removed is usually muddy and somewhat slimy on the top when wet, and forms a slight crust when allowed to dry. The mud and discoloration, which determine the depth of removal, extend from one-half to three-fourths of an inch down into the sand, and impart an adhesive quality to the sand, by virtue of which in cleaning, the scraper seems to follow a line of cleavage between the foul and clean portions of the bed.

After a bed has been cleaned the connection between the ground water well and the filtered water well is partially opened, and the water level in the effluent chamber gradually raised thereby until the newly cleaned bed is fully submerged to the depth of about a foot by the filtered or clear water, after which the raw water inlet is opened, the ground water again excluded, and the cleaned filter is thus again installed in service.

The time required for cleaning one of the beds of one-sixth of an acre is half a day, and the total cost thereof about $8.50, made up as follows: —

3 men scraping	½ d. at	$1.50	each,	$2 25
2 men wheeling in filter	"	1 50	"	1 50
1 man tending bucket at bottom	"	1 50	"	75
2 men to land and dump bucket at top	"	1 50	"	1 50
1 man wheeling away on top	"	1 50	"	75
1 single team to hoist bucket	"	2 50	"	1 25
Tools and sundries				50
				$8 50

This is at the rate of about $50 per acre per cleaning, not including replenishing.

The entire cost of cleaning and maintenance, including that of restoring the sand removed, for one year, to Feb. 28, 1897, is estimated as follows: —

Number of compartment cleanings, 29.	
Labor for each scraping, using such men employed about the works as are available, and hiring others at an extra expense of $4.50, but charging all labor employed as above	$8 50
Cost for 29 cleanings	246 50
Average reduction in depth of sand beds, taking all three compartments into consideration, is about nine inches, to replenish which requires 610 cubic yards, at $1.00 placed	610 00
Making cost of cleaning and replenishing	$856 50
Add for contingencies and superintendence, 5%	42 87
Total cost	$899 37

Average per cleaning, including replenishing, per compartment,	$31 01
Average per cleaning, including replenishing, per acre . .	186 06
Million gallons filtered, March 1, 1896, to Feb. 28, 1897 . .	397.86
Cost per million gallons filtered, not including interest on plant,	$2 26

The average rate of filtration per acre per day (rated on one-half acre in use) was 2,180,064 gallons.

The interest charge per million gallons filtered, computed on the actual cost of the plant, at the different rates indicated below, and added to the above cost of operation, gives the following results: —

RATE OF FILTRATION 2,180,064 GALLONS PER ACRE PER DAY.

Rate of Interest.	Interest Charge per Million Gallons.	Cost of Operation per Million Gallons.	Total Cost of Filtration per Million Gallons.
6 per cent . . .	$6 06	$2 26	$8 32
5 " " . . .	5 05	2 26	7 31
4 " " . . .	4 04	2 26	6 30

Increasing the rate of filtration within moderate limits, say to not exceeding 3,000,000 gallons per acre per day, would not materially affect the operating cost per million gallons filtered, since the number or frequency of cleanings would be approximately proportional to the rate of filtration. The interest charge per million gallons filtered, however, is inversely proportional to the rate of filtration or the amount filtered. Thus if the rate of filtration were 3,000,000 gallons per acre per day, the interest charge and total cost of filtration resulting therefrom at the several rates of interest indicated would be as follows: —

RATE OF FILTRATION 3,000,000 GALLONS PER ACRE PER DAY.

Rate of Interest.	Interest Charge per Million Gallons.	Cost of Operation per Million Gallons.	Total Cost of Filtration per Million Gallons.
6 per cent . . .	$4 40	$2 26	$6 66
5 " " . . .	3 67	2 26	5 93
4 " " . . .	2 93	2 26	5 19

The cost of operation will vary in different years according to the variable conditions of the problem, such as duration and degree of muddiness of water in the bay, cost of sand, improvement in method, etc.; and in making deductions from the experience at Ashland, for the proper study of the problem of filtration at other places, all such conditions must be carefully compared and considered.

First among the conditions which experiment and experience in slow sand filtration have shown to be prerequisite to a high degree of efficiency, as indicated by comparative bacterial analyses of the raw and filtered water, is the lapse of time necessary for the establishment of bacterial life or soil organisms throughout the filter bed, whereby the individual sand grains appear to become invested with or covered by a gelatinous coating of "zoöglœa" upon the chemical or organic action of which the removal or destruction of pathogenic germs by the filter is believed to largely depend. The process is therefore *vital* as well as mechanical, and the time required to develop this condition Mr. Hazen has aptly termed "the period of biological construction."

The development or establishment of such a biological organization *where the sand composing the filter bed has not been sterilized* or its natural bacterial condition has not been materially changed has been found to be a process requiring some months, and indeed some of the Lawrence experiments tend to show a constantly increasing bacterial efficiency during the first two or three years' operation.

It appears further to have been well established by experiment that a filter bed of sand which has been *sterilized by heating* yields for a time an effluent containing relatively more bacteria than one of unsterilized sand, sometimes more than were contained in the raw water. Such results have been attributed to the inferior or impaired efficiency of the sterilized sand in destroying or removing the bacteria of the raw water, but the Lawrence experiments appear to indicate in some cases at least "that the high numbers, often many times as high as in the raw water, do not represent bacteria which pass in the ordinary course of filtration, but instead, enormous growths of bacteria throughout the sand supported by the cooked organic matter in it." *

It should be here stated, however, that the investigations thus far made at Ashland show that the bacteria in the filtered water have borne some relation in numbers — although not clearly so in kind, so far as varieties have been differentiated — to those found in the raw water at the same time.

To what extent, if any, a sand drafted from the bed, or taken from a beach of Lake Superior, may be lacking in those normal *soil*

* Hazen, Filtration of Public Water Supplies, p. 81, 1st edition.

bacteria, upon the existence of which throughout the filter bed its efficiency in the removal and destruction of water bacteria is believed to largely depend, or what additional length of time may be required to establish and complete in such sand, or in sand sterilized by heat, the process of biological construction referred to is a question to which, so far as I have been able to learn, neither experience nor experiment has yet supplied the answer. That such period must be greater than in the case of sand from land sources, in which the normal bacterial conditions have not been changed by sterilization or otherwise, can hardly be doubted, and the possible significance of such considerations should not be overlooked in considering the bacterial efficiency of the Ashland filter during the first year or more of its operation in view of the fact that the sand in two of its compartments was in all probability completely sterilized by the heating process to which it was subjected during the winter season in which it was constructed, and that all of the sand was obtained from sources and by processes which subjected it to a very thorough washing with clear lake water, whereby such bacteria as remained in it were presumably of water rather than soil varieties.

Other conditions which contribute to a low efficiency of filtration during the first year's operation of this filter, all of a temporary character are —

(*a*) The high average rate of filtration necessitated during the use of two compartments only, during the first seven months of that period, and one only when the other was being cleaned.

(*b*) Fluctuations in the rate of filtration at the time samples were taken during the first part of that period, by reason of the exclusion of ground water during the half hour of taking.

(*c*) The time intervening between the taking of the samples at Ashland and the biological examination of the same at Madison, — usually a full day.

(*d*) The lack of automatic regulation of the rate of filtration upon each of the several filter beds, for which provision is now being made.

Notwithstanding these considerations and the incomplete stage to which the filter had been brought, the city authorities, at the suggestion of the writer, instructed the Health Commissioner, Dr. E. D. Perkins, to have biological analyses of the raw and filtered water made "every thirty days or oftener," beginning with the first

Operation of Sand Filter at Ashland, Wis., and Bacterial Analyses of Results by Prof. H. S. Russell, of Madison, Wis.

TABLE A, covering first period from Feb. 8, 1896, to July 3, 1896.

CONDITIONS. — Compartments Nos 2 and 3 only, in use. Filtration Area, 1/3 Acre. Compartment No. 1 (having no filter bed), in open connection with Effluent Chamber and Pump Well. Overflow from Collecting Well into Effluent Chamber, amounting to 252,000 Gallons daily, is continuous, except for a short time (about thirty minutes) before samples are taken, during which interval said overflow is excluded, thereby increasing the daily rate of filtration during that time by 252,000 ÷ 1/3 = 756,000 Gallons per Acre.

Samples Taken.	Samples received at Madison.	Temperature Fahr. on arrival.	Bacteria Found, Number per cc.			Analyst's Remarks.	Approximate Rate of Filtration per Acre in Gallons per Day.			Compartments of Filter Cleaned.	
			Unfiltered.	Filtered.	Apparent reduction per cc. by Filtration, per cent.		When samples were taken.	Maximum since previous sample was taken.	Minimum since previous sample was taken.	Date.	Compartment.
1896.											
Feb. 19, 5.00 P. M.	Feb. 20	41.	1,475	1,258	14.7		5,517,600	5,517,600	2,589,600		
Feb. 26, 5.00 P. M.	Feb. 27	41.	960	870	9.4	Gas-producing bacteria present in unfiltered sample, absent in filtered.	4,620,000	4,846,800	3,012,000		
March 27, 5.00 P. M.	March 28	41.	4,500	1,000	77.7		5,029,200	5,110,800	2,642 400		
April 10, 5.00 P. M.	April 11	44.	5,310	425	92.		4,382,400	4,382,400	2,695,200		
April 24, 5.00 P. M.	April 25	44.	19,000	10,300	45.8		4,290,000	4,290,000	2,259,600		
										April 27	No. 3.
										April 28	No. 2.
May 1, 5.00 P. M.	May 2	52.	68,800	48,000	30.2		3,788,400	6,736,800	2,088,000		
May 8, 4.30 P. M.	May 9	52.	2,230	1,760	21.1		4,540,800	4,540.800	2,048,400		
May 15, 4.30 P. M.	May 16	40.	1,000	320	68.		4,646,400	8,067,600	2,312,400		
										May 18	No. 3.
										May 19	No. 2.
May 22, 4.30 P. M.	May 23	44.5	185	37	80.		4,950,000	7,106,400	2,233,200		
										May 29	No. 3.
										June 1	No. 2.
										June 10	No. 2.
June 12, 4.30 P. M.	....	43.	4,185	275	93.4	Raw water contains gas-producing bacteria; filtered product, none.	4,237,200	7,687,200	1,956,000		
										June 13	No. 3.
June 19, 4.30 P. M.	June 20	48.	700	130	81.4	Liquefying forms present in unfiltered sample, absent in filtered; fæcal bacteria absent in both.	5,121,600	7,423,200	2,470,800		
										June 22	No. 2.
										June 26	No. 3.

June 29, 4.30 P. M.	June 30 ...	41.	1,115	615	44.9	Species commou in unfiltered sample are almost wholly absent in the filtered product.	5,134,800	8,822,400	2,457,600	June 30	No. 2.
July 3, 4.30 P. M.	July 4....	44.5	2,300	480	79.1	All liquefying and gaseous organisms removed.	4,725,600	8,901,600	2,589,600		

TABLE B, covering second period from July 4, 1896, to July 31, 1896.

CONDITIONS. — Same as in Table A, except that the discharge from the Collecting Well, being diverted from the Effluent Chamber to the Pump Well, flows continuously, thus maintaining the same rate of Filtration at time samples are taken, which obtains before and after.

Samples Taken.	Samples received at Madison.	Temperature Fahr. on arrival.	Bacteria Found, Number per cc.			Analyst's Remarks.	Approximate Rate of Filtration per Acre in Gallons per Day.			Compartments of Filter Cleaned.	
			Unfiltered.	Filtered.	Apparent reduction per cc. by Filtration, per cent.		When samples were taken.	Maximum since previous sample was taken.	Minimum since previous sample was taken.	Date.	Compartment.
1896.										July 6 July 10 July 16	No. 3. No. 2. No. 3.
July 17, 4.30 P. M.	July 18....	41.	1,720	920	46.5	Gaseous and liquefying organisms in both filtered and unfiltered samples.	3,434,400	8,637,600	2,074,800		
July 24, 4.30 P. M.	July 25....	46.	1,150	150	86.9	Gaseous and liquefying organisms present in unfiltered samples, practically absent in filtered product.	3,698,400	7,317,600	2,167,200	July 21	No. 2.*
July 31, 4.00 P. M.	Aug. 1...	45.	1,580	408	74.2	Gas producing bacteria present before filtration, but absent in samples taken after.	4,200,000	7,608,000	2,391,600	July 28	No. 3.†

* Compartment No. 3 furnished all the filtered supply from 8.00 A. M. to 1.00 P. M.
† Compartment No. 2 furnished all the filtered supply from 7.00 A. M. to 1.30 P. M.

TABLE C, covering third period from Aug. 1, 1896, to Aug. 31, 1896.

CONDITIONS. — Same as in Table B, except Compartment No. 1, meanwhile receiving its filter bed, is shut off from the Effluent Chamber and so cease to act as a compensating reservoir.

Samples Taken.	Samples received at Madison.	Temperature Fahr. on arrival.	Bacteria Found, Number per cc.			Analyst's Remarks.	Approximate Rate of Filtration per Acre in Gallons per Day.			Compartments of Filter Cleaned.	
			Unfiltered.	Filtered.	Apparent reduction per cc. by Filtration, per cent.		When samples were taken.	Maximum since previous sample was taken.	Minimum since previous sample was taken.	Date.	Compartment.
1896.										Aug. 4	No. 2.*
Aug. 6, 11.00 A. M.	Examined at Ashland immediately.	44.	1,625	1,460	10.1	Taken by Prof. Russell, personally. Liquefying bacteria almost entirely removed by filtration.	3,711,600	8,056,800	2,352,000		
Aug. 6, 11.00 A. M.	Examined after twenty hours.	44.	1,820	1,740	4.4	Taken by Prof. Russell, personally. Liquefying bacteria almost entirely removed by filtration.	3,711,600	8,056,800	2,352,000		
Aug. 7, 9.30 A. M.	Examined at Ashland immediately.	......	2,200 170 Liquefying.	2,700 25 Liquefying.	—22.7 85.3	Taken by Prof. Russell, personally. Filtered sample had more bacteria than unfiltered, but much less liquefying organisms.	3,975,600	4,134,000	3,078,000		
										Aug. 12	No. 3.†
Aug. 17, 3.00 P.M.	Aug. 19...	43.5	1,260	30	97.6	Gaseous organisms present in unfiltered, absent in filtered sample.	3,474,000	6,948,000	2,193,600		
										Aug. 20 Aug. 28	No. 2.‡ No. 3.§

* Compartment No. 3 furnished all the filtered supply from 6.40 A. M. to 1.15 P. M.

† Compartment No. 2 furnished all the filtered supply from 7.45 A. M. to 1.15 P. M.

‡ Compartment No. 3 furnished all the filtered supply from 8.40 A. M. to 3.15 P. M.

§ Compartment No. 2, with the Collecting Well, furnished all the supply between 12.30 and 3.45 P. M., and without the Collecting Well furnished the supply from 11.00 A. M. to 12.30 P. M., and from 3.45 to 5.30 P. M.

TABLE D, covering fourth period, from Sept. 1, 1896, to Feb. 19, 1897.

CONDITIONS. — Compartments numbered 1, 2 and 3 in use. Filtration Area, ½ Acre. Overflow from Collecting Well, discharging continuously (as in Tables B and C) into the Pump Well at the rate of 252,000 gallons each 24 hours.

Samples Taken.	Samples received at Madison.	Temperature Fahr. on arrival.	Bacteria Found, Number per cc.			Analyst's Remarks.	Approximate Rate of Filtration per Acre in Gallons per Day.			Compartments of Filter Cleaned.	
			Unfiltered.	Filtered.	Apparent reduction per cc. by Filtration, per cent.		When samples were taken.	Maximum since previous sample was taken.	Minimum since previous sample was taken.	Date.	Compartment.
										Sept. 1*	
										Sept. 2	No. 2†
										Sept. 9	No. 3‡
Sept. 25, 5.00 P. M.	Sept. 26	41.	450	100	77.7	Vigorons growth of gas organisms in unfiltered sample; none in filtered.	2,518,400	8,400,000	1,374,400		
Oct. 5, 4.30 P. M.	Oct. 6.	41.	1,085	30	97.2	Liquefying bacteria in unfiltered, none in filtered sample. Unfiltered had bad type of sewage bacteria; filtered, none.	2,615,200	2,668,000	1,242,400		
										Oct. 8	No. 1.
Oct. 12, 4.30 P. M.	Oct. 13	42.	200	40	80.	Small amount of gas-producing germs in unfiltered sample; none in filtered.	2,228,000	3,474,000	1,436,000		
Oct. 23, 4.30 P. M.	Oct. 24	37.	850	65	92.3	Copious amount of gas-producing germs in unfiltered sample; none in filtered.	2,580,000	3,196,000	1,436,000		
										Oct. 27	No. 2.
Oct. 30, 3.00 P. M.	....	38.	2,700	30	98.5	Abundant gaseous fermentation in unfiltered sample; none in filtered.	2,404,000	3,606,000	1,524,000		
Nov. 6, 3.00 P. M.	....	37.	2,300	75	96.7	Liquefying and gaseous bacteria quite prevalent in unfiltered sample; none in filtered.	2,052,000	2,316,000	1,260,000		
										Nov. 12	No. 3.

* Compartment No. 1 placed in operation.

† Replenished sand bed in No. 2, increasing thickness of same 4½ inches above original depth and again placed in operation, Sept. 8, 1896.

‡ Replenished sand bed in No. 3, increasing thickness of same 4½ inches above original depth and again placed in operation, Sept. 13, 1896.

TABLE D — *Continued.*

Samples Taken.	Samples received at Madison.	Temperature Fahr. on arrival.	Bacteria Found, Number per cc.			Analyst's Remarks.	Approximate Rate of Filtration per Acre in Gallons per Day.			Compartments of Filter Cleaned.	
			Unfiltered.	Filtered.	Apparent reduction per cc. by Filtration, per cent.		When samples were taken.	Maximum since previous sample was taken.	Minimum since previous sample was taken.	Date.	Compartment.
Nov. 13, 4.00 P. M.	....	37.	675	88	87.	Unfiltered sample contained organisms of fæcal type; filtered, none.	2,110,000	3,132,000	1,436,000		
Nov. 27, 3.30 P. M.	....	36.	700	175	75.	Liquefying and gaseous bacteria both present, although to a limited extent.	2,228,000	2,756,000	1,524,000		
										Nov. 28	No. 1.
Dec. 11, 4.00 P. M.	....	38.	4,800	1,825	62.	Liquefying and gaseous bacteria present in both filtered and unfiltered samples, although much less in filtered than in unfiltered.	2,492,000	4,002,000	1,700,000		
										Dec. 12	No. 2.
Dec. 20, 4.30 P. M.	Dec. 21...	37.	2,890	1,860	35.6	Liquefying and gaseous germs present in both filtered and unfiltered samples.	2,048,000	3,474,000	1,684,000		
Dec. 25, 5.00 P. M.	Dec. 26...	39.	7,600	2,300	69.7	Gaseous bacteria present in large numbers in unfiltered sample, but absent in filtered.	2,020,000	2,748,000	1,264,000		
										Dec. 26	No. 3.
Dec. 29, 10.00 A. M.	....	41.	....	2,875	—35.6	Sample from Compartment No. 1, 31 days since cleaning. Bacteria increased in numbers over unfiltered, but no liquefying or gaseous germs found.	2,192,000	3,324,000	1,684,000		
Dec. 29, 2.25 P. M.	....	41.	....	2,900	—36.8	Sample from Compartment No. 2, 17 days since cleaning. Bacteria increased in numbers over unfiltered, but all liquefying and gaseous germs removed.	2,300,000	3,324,000	1,684,000		

Dec. 29, 5.00 P. M....	....	41.	....	2,500	—17.9	Sample from Compartment No. 3, 3 days since cleaning. Bacteria increased in number over unfiltered but no liquefying and few gaseous germs found.	2,300,000	3,324,000	1,684,000		
Dec. 29, 2.30 P. M.........	....	41.	2,120	... .	....	Unfiltered sample, with which the three preceding samples are compared, contained copious quantities of both liquefying and gaseous germs.	2,300,000	3,324,000	1,684,000		
1897. Jan. 8, 3.30 P. M..........	Jan. 9.....	......	4,100	770	81.2	Liquefying and gaseous germs in abundance in unfiltered sample, but no trace in filtered.	2,512,000	2,524,000	1,576,000		
Jan. 15, 4.00 P. M.........	....	42.	2,500	110	95.6	Liquefying and gaseous germs quite plentiful in unfiltered sample, wholly absent in filtered.	2,588,000	3,620,000	1,712,000		
Jan. 22, 3.00 P. M..	Jan. 23....	33.	1,950	90	95.4	Numerous gas-producing bacteria in unfiltered sample, none in filtered.	2,728,000	3,376,000	1,544,000		
Jan. 29, 2.00 P. M....	....	35.	1,680	540	67.2	Filtered sample free from gaseous germs, unfiltered having the usual number.	2,524,000	4,134,000	2,272,000	Jan. 27	No 1.
Feb. 5, 3.00 P. M.........	....	32.	4,450	445	90.	No gas-producing germs present in filtered sample, although plentiful in unfiltered.	2,300,000	2,664,000	1,516,000		
Feb. 19, 2.30 P. M.........	Feb. 20...	45.	480	50	88.9	No gas-producing germs present in filtered sample, although unfiltered contains them in copious quantities.	2,300,000	2,580,000	1,600,000		

operation of the filter in February, 1896. For this purpose Prof. H. L. Russell of the Wisconsin University, at Madison, was selected by Dr. Perkins to direct the taking of samples and to make the analyses thereof. And while for the reasons and causes stated the apparent biological results of filtration shown from these analyses are not to be considered indicative of the true value or practical efficiency of the filter, even during the first year's operation, — and much less for the future when its normal condition and regulation shall have become fully established and provided, — nevertheless, the results of the analyses made for the first year are given herewith for what they may be worth, tabulated in four subdivisions made according to the varying conditions existing throughout different portions of the year.

While authorities differ as to the value to be ascribed to bacterial analyses of raw and filtered water as bases for demonstrating the hygienic value or efficiency of filtration, the evidence afforded in actual mortuary statistics during a long term of years seems to merit and to receive general acceptance as a reliable indication of the practical worth of filtration. The true value of such statistics is found only in their broad general application. Limited to single and especially to small communities, where as at Ashland discrepancies and lack of uniformity in the identification and designation of diseases exists, and where the records cover a comparatively brief period at the best, during one year only of which filtration has been practised, they can have only a remote or, at the best, a cumulative value, yet such indications as they afford in the case of Ashland are in the desired direction, *i. e.*, in support of the assumption that sand filtration, even in the incompleteness of its first year, has had a favorable effect upon the public health, especially in its bearing upon such diseases as are to some extent at least promoted by or communicated through sources of water supply, as may be seen from the following table : —

CITY OF ASHLAND, WIS.

Summary of statistics of deaths for five years from March 1, 1892, to March 1, 1897, compiled from physicians' certificates of causes of deaths, filed with the health officer of Ashland.

Statistics of December, 1892, and March, 1893, are missing from the records, and therefore are not included in this summary.

Year.	Certified Causes of Deaths				Remarks.
	Typhoid Fever.	Winter Cholera, Summer Complaint, Bowel Complaint, Diarrheal Diseases, Dysentery, Inflammation of the Bowels.	Other causes, specified and unspecified.	Total.	
March, 1892, to February, 1893 ..	11	4	163	178	December not included. Records missing.
March, 1893, to February, 1894 ..	32	17	216	265	March not included. Records missing.
March, 1894, to February, 1895 ..	40	15	171	226	
March, 1895, to February, 1896 ..	11	10	196	217	Filtration of water began and all use of raw water discontinued Feb. 8, 1896.
March, 1896, to February, 1897 ..	7	6	162	175	

DISCUSSION.

Mr. Hazen. I think the thanks of the Association, and of every one who is interested in covered filters or covered reservoirs, are due to Mr. Wheeler for showing us this vaulting. It has been my privilege to examine covered reservoirs and covered filters in a great many cities. There are, as you know, many different systems of vaulting. The older vaultings had lintel arches with a higher row of covering arches sprung from them in another direction. This style of construction was easily built, and was commonly used. It required a rather large amount of masonry, and was not well adapted to filters, because it cut off the head-room in one direction, or else necessitated carrying the side walls and the vaulting up a good deal

higher than would otherwise be necessary. Then the French perfected a system of groined arches with extraordinarily thin masonry, which was, however, somewhat difficult to place and keep in order, so that an American engineer once said that it represented the minimum of material and the maximum of expense. Then there are other filters and reservoirs covered with thicker groined arches. I have a book describing the vaultings used in the Roman reservoirs in Constantinople. Some have very elaborate and most wonderful carving in the vaulting and support; one can hardly understand why such work was put into reservoirs. This style of vaulting requires a great deal of masonry, and, aside from the carving, is necessarily rather expensive. The groined arch work in the newer German reservoirs often has ribs, something like those in Gothic churches. These ribs are apparently regarded as necessary, either to help them in construction, or to take up the extra strain at the corners.

Mr. Wheeler has shown us a vaulting which is free from all this extra masonry, plain and simple, as you have seen from his splendid photographs, and which has proved entirely stable and satisfactory, and he deserves our thanks for showing us how it can be done.

Mr. Knowles. I would like to ask Mr. Wheeler if he can tell us something about the cost of running the filter. I did n't hear him say anything about the cost of washing the sand, and I would like to have him tell us about that and how it is done.

Mr. Wheeler. No sand washing is done at Ashland. The sand is delivered on the dock at a price that, without trial, we have supposed to be as low, or probably lower than, we could wash old sand for. The price of the new sand which was used last September for replenishing two compartments was ninety cents per cubic yard, for the sand delivered through the manholes on to the bed, but not distributed, placed. The preceding year the sand cost us sixty-five cents per cubic yard delivered on our land, ready to be barrowed to the manholes and deposited on the bed; hence we have had no occasion to wash any sand.

Mr. Coffin. I understood Mr. Wheeler to say that the Holly system was used, from which I suppose the pumping is at the ratio of the consumption.

Mr. Wheeler. Yes, sir.

Mr. Coffin. I have begun some slight studies on the distribution of draught, and of course we all know it is quite varying. I find in

several cases that it runs as high, at certain hours of the day, as 210 or 212 per cent of the average for the day, and in some cases over 300 per cent of the average for the year. Of course, I don't know how that would apply to this plant, but I would like to ask Mr. Wheeler if he has given any attention to that matter in connection with his filters, and at what time in the day the samples were taken for analysis, and if that would not be likely to reduce the efficiency, or apparently reduce the efficiency, of the filters, if the samples were taken, say, along about eight or nine o'clock in the forenoon.

Mr. Wheeler. There is no doubt, Mr. President, that the efficiency of the filters during the past year, as appears in these tables, is very much less by reason of the irregular rate of filtration, that rate being practically the varying rate at which the water is used in the city, the range of which I have no doubt is sometimes as great as Mr. Coffin has found in other cases. The provision, to which I alluded, for regulating the rate of filtration, which is now in construction, will not only regulate the inflow, equalize the filtration in each compartment, but in case of excessive draught will provide for the opening of a connection from the ground water well, so that excessive draught will be supplied from that source, as we have in store some 300,000 gallons above the level at which the water usually stands in the filtered water pump well. The highest rate of filtration, or the ranges of the rate of filtration, which I am now able to give you, are simply the maximum and minimum daily pumpage, which, so far as I have been able to learn from the pumping station record book, which I have now at my office, has been from 1,100,000 gallons per day to about 2,150,000 gallons per day as the maximum. That maximum was upon the day of a very hot fire, the burning of one of the large lumber yards and docks, of which there are several in Ashland.

TESTING WATER PIPE DISTRIBUTION SYSTEMS.

BY F. L. FULLER, C. E., BOSTON, MASS.

[*Read Feb.* 10, 1897.]

Specifications for cast iron water pipe generally call for the application of a pressure of 300 lbs. per square inch at the foundry, in order that any imperfections may be detected. This in connection with the hammer test is likely to show the presence of any cracks or sand holes. If these requirements are complied with, it is reasonably certain that when the pipe leaves the foundry it is free from these defects.

Pipe is, however, very often cracked in transportation. This is especially the case when delivered by rail. During the hurry of switching, with its sudden starting and stopping, pipes often strike each other with considerable violence, and cracks, especially at the spigot ends, are likely to result.

The cracks in some of these pipes may be detected at the time of unloading from the cars, but in many cases they are so fine as to be difficult of discovery. The pipes are liable to still further injury while being hauled from the cars to the street where they are to be laid, and even while lying upon the street until they can be put in the ground. In new works, especially if the pipe is delivered in the winter, considerable time may elapse between delivery on the ground and laying. It is therefore possible, that with the greatest care and the closest inspection, some cracked pipe may be laid.

Of course, when possible, the water should be let on and the pipes flushed and tested before the backfilling is done. As a general thing this can only be done in cases of short extensions, where the work is done by the town or city by days' labor, or where the pipe is not laid in the highway. A contractor is naturally anxious to complete both the pipe laying and backfilling upon a given street before moving his men to another. It is also usually desirable to interfere with the use of the street for public travel for as short a time as possible.

On account of the time required to properly flush and test the pipes, and also on account of the fact that in the case of a new

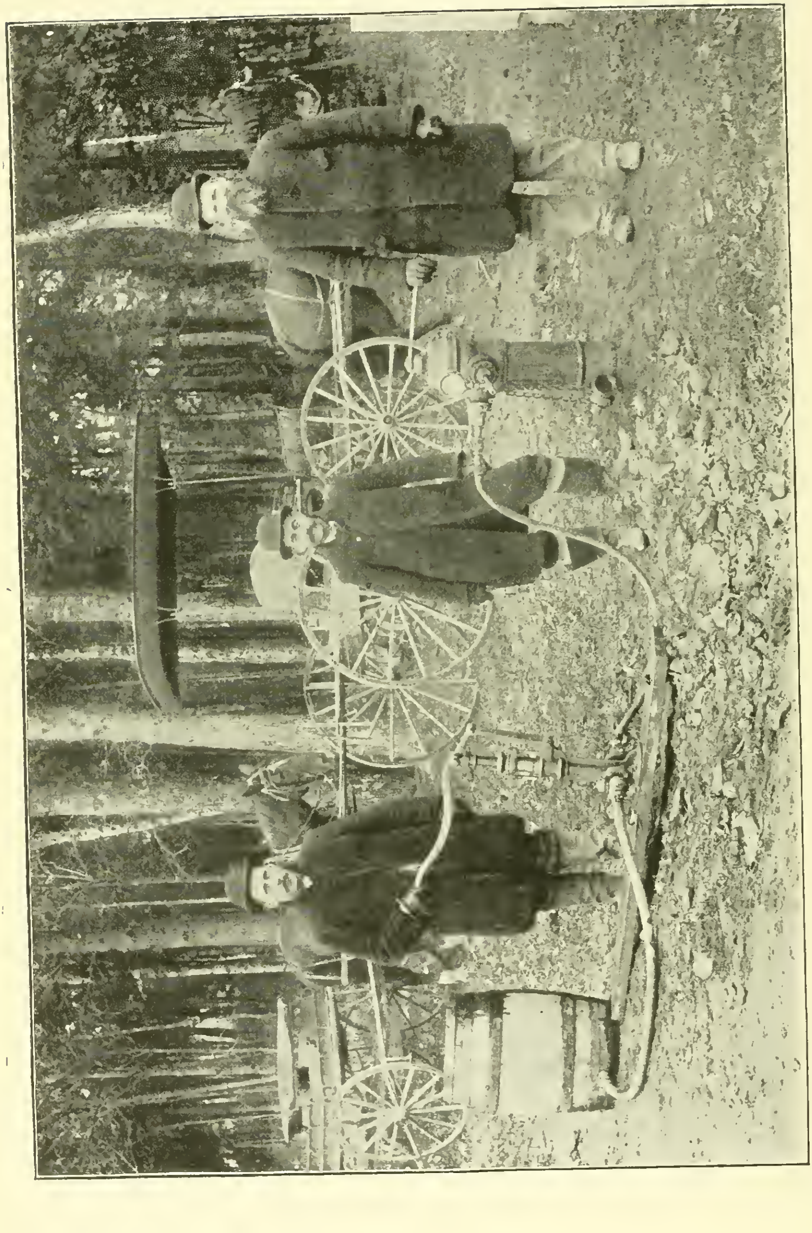
system, the pumping machinery and reservoir are generally the last things to be completed, it follows that this testing is usually done after the works are practically finished.

When the water is let on to the system, if the pressure is considerable, some of the damaged pipes may be split open, or the cracks opened sufficiently to discharge water enough to appear at the surface. This is also true of imperfectly made joints. Still there are many leaks which do not appear at the top of the ground. This may be because they are small and do not saturate the soil to the surface, or because they are in pipes laid through loose, porous material which allows the water to drain off easily. Leaks or imperfect joints may occur in trenches in rock cuttings which have been partially refilled with broken stone, or near brook or river crossings or culverts.

Under such conditions leaks may exist for years unnoticed, unless some method is employed to thoroughly test the pipes after they are laid in the ground. The amount of water which is lost in 24 hours, through even a small leak is surprising, and may account for the large amount of water pumped and supposed to be used by some towns. A stream so small that it is on the point of turning into separate drops, as obtained at an ordinary faucet, amounts to 25 gallons in 24 hours, or over 9,000 gallons in a year. One hundred such leaks amount to over 912,000 gallons in one year. Most leaks would be much larger than the above, and in a system which had not been tested, the number might be greater.

In order to easily test a system of water pipes, a sufficient number of gates must have been put in, to allow the pipe to be shut off in small sections. It is of course easier to locate a leak within small limits than within large ones. Local conditions will have something to do with the frequency of the gates, but it is well not to be obliged to shut off more than 1,500 feet at a time. When there are many intersections, caused by numerous streets crossing each other, the length of pipe in a section would be likely to be less. It is well to test a pipe system after as many services as possible have been put in, but before the water has come to be much used. By shutting the stop and waste cock on the inside of the cellar wall, the service pipes, including the corporation cock and the flexible lead connection and its joints, are tested, as well as the street mains.

One of the easiest ways of getting an approximate idea of the tightness of a section, is to attach a pressure gauge to a hydrant and



TESTING PUMP ATTACHED TO HYDRANT.

shut the gates which inclose it; also all the stop and waste cocks within the section.

If there are no leaks, or but very small ones, the pressure will fall slowly, or scarcely at all. There may be cracked pipe, or perhaps poor joints, but the static pressure from reservoir or stand pipe may not be sufficient to cause such leakage. Still a cracked pipe should not be allowed in a pipe system, even if it does not leak at the time, for the crack is liable at any time to become larger and make trouble. The flow into the section through a gate which is not tight may make good the loss of water from a small leak, and the pressure be kept up. It might also happen that another gate might allow the passage of water out of the section into another where the pressure was less. The shutting of additional gates might remove some of the uncertainty caused by these defects. It does not require a great deal of time to go over a pipe system of moderate size in this way, and it gives some idea of where leaks may be expected.

The next step should be the use of a hand testing pump connected by a flexible rubber steam hose to one nozzle of a hydrant. To the second nozzle should be attached a pressure gauge. The pump should be mounted on a plank and have a rubber section hose which can be connected to a barrel or tub. The pump referred to, with the necessary fittings, costs about $30. It has a piston one and a half inches in diameter and has a stroke of about six inches. At the ordinary speed of working, the pump would throw about three gallons per minute. This is practically a boiler testing pump, and a pressure of two hundred to three hundred pounds per square inch can easily be obtained, provided the section being tested is tight. The pump has a check valve on both suction and discharge sides, and an additional check valve can be placed in the suction hose near the barrel. There should also be a globe valve on the discharge hose near the hydrant, which can be closed when the pressure has been raised to the desired amount, in order to see whether this pressure can be maintained.

The barrel holding the water to be pumped into the section should have a scale or graduation on the inside, so that the number of gallons pumped per minute can be ascertained.

It is necessary to observe at least two precautions. First, the pipes being tested should be entirely filled with water. If there are pockets of air at any of the summits, the air will be compressed and

act as a cushion, and the desired pressure will not be obtained. The pressure gauge will not be apt to drop back when the pump is stopped, which may give a clew to the trouble.

Second, the drip of the hydrant to which the pump and gauge are connected must close tightly, so that there is no leakage. Sometimes when the desired results cannot be obtained at a certain hydrant, it may be well to change to another where the drip may close better.

It requires three men to do the testing, and if the water to be pumped has to be brought far, a fourth man will be found advantageous. Careful notes should be kept of the results obtained at each section.

If after properly shutting off the section, the pressure can be raised to two hundred or two hundred and fifty pounds, and on shutting the globe valve on the discharge, remains so for ten minutes or more, it may be concluded that the section is tight and the apparatus moved to another section and the operation repeated.

If by continuous pumping the pressure cannot be raised, it is evident that a leak exists.

The amount of water it is necessary to pump into the section per minute to maintain the normal static pressure shows the amount of water that is ordinarily running to waste from that section. If a fair amount of pressure can be maintained by the pump, it shows that the leak is not a large one at that time. Just what is the cause of it can only be guessed.

If, on applying the pump to a closed section, the pressure is low and the full capacity of the pump does not increase the pressure, it is evident that a considerable leak exists, and that it amounts to more than three gallons per minute.

After having been over the entire system with the hand pump, recourse should be had to a piston steam fire engine, if it can be obtained. If it cannot, a steam pump of about 150 gallons a minute capacity, and capable of exerting a pressure of 200 to 300 pounds per square inch, will answer the purpose. A No. 7 boiler feed or pressure pump having a ten-inch steam cylinder, a six-inch water cylinder and twelve-inch stroke with a capacity at 100 strokes per minute of 150 gallons, will be found convenient.

A boiler capable of furnishing steam at 100 pounds pressure will be necessary to run the pump.

Either the steam fire engine or the steam pump should be applied

to all doubtful sections. This can be done by placing the steamer or steam pump within fifty feet of a hydrant located outside of the section to be tested. This hydrant will be under reservoir or standpipe pressure. One length of hose will furnish water to the suction of the steamer or pump. Another line of hose will connect the steamer or pump with an open hydrant within the section to be tested. This latter line of hose must, of course, be strong enough to stand the desired pressure to be put upon the pipe. The pressure should be applied gradually and carefully. By this means enough water can be forced into the section to break any cracked pipe, or force water enough through a poor joint to appear at the surface. It usually takes but a few minutes to show the cause of the leak. After it has been repaired, the testing with the hand pump should be repeated.

In this way it is possible to be quite certain that a pipe system is practically tight. If possible, a pipe system should be thoroughly tested every three or four years.

When pipes are to be laid in deep trenches or cuttings or under railroads or streams where they will be difficult of access in case of leaks, it is a great advantage to test these pipes just before they are laid. By bolting on a proper head or cap at each end and filling with water, and connecting the pump with one of the heads, the pipe can easily be tested to any desired pressure.

The writer has tested a number of pipe systems in the manner described, with very satisfactory results.

[Mr. Fuller then showed the pump and connection as used, and explained their operation.]

DISCUSSION.

Mr. Hyde. I would like to ask how that would work with leaky gates.

Mr. Fuller. Leaky gates are troublesome things. I wish that we could have gates that did not leak. One remedy is to shut off surrounding gates so as to get the advantage of two gates in place of one.

Mr. Walker. I would like to ask Mr. Fuller whether, in case he had a pipe, the spigot end of which was cracked for three and one half inches and the bell was four inches deep, whether he would throw it out or put it in.

Mr. Fuller. I should think, if the crack at the spigot end came

within the bell, there would not be much trouble from it. I suppose the safer way would be to cut it off. I should say that would be the better way to do and get rid of the crack.

Mr. Walker. We have laid a great many pipes that were cracked three and a half inches, and the bell four inches deep, and there has been no trouble for two or three months, when all at once there would be a great leak and we would find the crack covered up by tar, notwithstanding it had lasted all that time.

Mr. Smith. I would like to ask Mr. Fuller if he thinks this method of testing has any advantage over using two meters. The way I test, when I have reason to believe I have trouble, is to attach a meter at the inlet and another at the outlet in any section and throw the water through the section, and if the meters register alike I consider the section tight. If I get a less flow from the outlet than from the inlet, I look for trouble in the section.

Mr. Fuller. Certainly Mr. Smith's method would be economical, but it seems to me that I should be a little better satisfied when I got through with this method than I should with his. If the gang of men are well organized they can go over the ground very quickly.

Mr. Crandall. I do not see the object in the use of the second meter.

Mr. Smith. If you have air pockets, your first meter will show a leak when no leak exists.

Mr. Hyde. The way we test our mains in Newton is to go around in the night, after 12 o'clock, perhaps, and shut off a section by closing the gates. We leave all those gates closed, perhaps fifteen or twenty minutes, then we open one gate through which the supply comes, and if there is a leak in that section you can hear the water going through that under the valve very plainly. If we find that there is a leak in that section we test all the service pipes, and as a general thing we find a leak in one or more of them, and perhaps a leak on the main, but ordinarily we find it without going all around. We find a little leak here and a little leak there, and after going around we find that most of that leakage comes from a leaky ball-cock, but we get a very correct idea of the leakage on our system in that way, which is very simple.

Mr. Fuller. I would like to ask Mr. Hyde how much of the water pumped could be accounted for in the consumption as registered by meters.

Mr. Hyde. I do not think we could get at that very closely; but if we find a leakage on a certain service pipe, by going to that house the next morning, if we find that they have a leaky ball-cock, we know that a certain amount has been wasted, and in that way we find all the leaks in that section.

Mr. Stacy. It looks to me as if the whole of this business is guess work. There are many things entering into this testing, and, unless it is very carefully done, and under the right conditions, the result is rather indefinite. That is, it is hard to decide whether it is a leak out of the pipe, or a leak in the gate, or a leak through the service pipe, or where it is. Now, we have never tested any of our pipes. Whenever we have had a leak that showed, of course we have fixed it. We have not had a general leak for something over a year. We have not averaged one a year that has come to our knowledge since the works were built. The one that we did fix about two years ago on Main Street, when we came to it, was about the size of a knitting needle. That showed at the surface, but if it had been in more porous ground it would not have shown at the surface. The hardest leaks that I have to discover have been those in the centre of the pipe. I had two or three of a 16-inch main, carrying a 160-pounds pressure. We found one of them almost by accident. It was just being run on to the skids into the trench. It happened in that carload of pipes that there were two others cracked in the middle, it being caused by dropping, I suppose, in transportation.

Mr. Coggeshall. I think Mr. Stacey is right on that matter of gates, — that you do not get them always tight the first time. In New Bedford, as Mr. Wood described at the last meeting, we have recently laid a 36-inch cast iron main some five miles in length from the new distributing reservoir to the centre of the city. This was laid by contract, and after it was completed last fall, and the reservoir also completed, it was decided to fill the reservoir, and the only way to do that was to pump back from the old pumping station, raising the water into this reservoir. The pumps at the present pumping station pump under a head of about 45 pounds pressure, and it was necessary to pump under a 75-pound pressure to raise the water into this reservoir. That we did by putting a little extra strain on, and pumped 68,000,000 gallons into that reservoir in thirty-one days, working night and day continuously. Then I thought it would be a good plan to see how tight it was, whether there were any leaks

on our distributing main; so we shut the sluice gate at the reservoir, and made sure that it was perfectly tight by entirely emptying the gate-house. Then we allowed the gate-house to fill up to the same level as the water in the reservoir and closed the gates, and also closed all connections with the present distributing system. In about two days' time the water had fallen in the gate-house less than two feet which indicated that there was a slight leak somewhere. Then we went down to the city end, where there were three gates connecting with the present distributing system, and opened those gates and closed them several times, and then we went up the pipe line about two thousand feet and closed a single gate, and that gate remains closed, and since then the water in the gate-house has kept its level perfectly, showing that there is scarcely any leak on that part of the pipe.

SERVICE GATE BOXES.

BY GEO. A. STACEY, SUPERINTENDENT, MARLBORO, MASS.

[*Read Feb.* 10, 1897.]

GENTLEMEN: I have had a little experience with service gate boxes, some of which has not been altogether satisfactory. Knowing that frost does not have the same effect in all localities I will state that the subsoil of Marlboro is largely clay and gravel hard-pan in which the clay predominates. This expands or heaves in the winter to a considerable extent, and in the spring when the ground begins to thaw out, it leaves the gate boxes from one to two and a half inches above the sidewalk. As this forms an obstruction they must be put down. Sometimes they can be driven down, but often the frost is not all out and an attempt to drive them results in the destruction of the top of the box. In this case, to save the box, I pump in hot water, and by this means succeed in getting them down without damage. The lifting of the box also lifts the base from the pipe and allows dirt and stones to get around the stop, so that after a time, in many cases, you cannot get the key on to the cock, or if you do succeed in that, you cannot shut it off. This is not very pleasant when the stop and waste in the building or the pipe back of it has burst and the water is flowing under from forty to one hundred pounds pressure into a cellar. The only remedy is to try and stop or retard the flow by a wooden plug or a clamp (at the same time getting a shower bath of not always warm water), then dig it up and reset the box.

Another source of trouble is that we find the covers off and broken by the carelessness of some plumber, or by a coal or other heavy team backing on to it, or by a small boy who uses it for a hub to play duck or pitch quoits to, and when he finds a box open, to help matters along, he proceeds to fill it with stones, and he usually finds one just about a fit. To get them out you must dig it up.

This is a small matter, taking the works as a whole, but it is one of the many little things that help make a superintendent's life miserable at times. Perhaps other works do not have much trouble

from this source, or use a box that obviates it. I do not think the boxes we have been using are the ones best adapted to our conditions. My idea of a box is one with the base of the lower section fitting closely to the pipe and stop, with a rather large flange to resist an upward pull and with the top section long enough to reach well down to or below the frost line. The inside diameter should be three quarters of an inch larger than the outside of the lower section, with three or four thin ribs or feathers on the inside, of such a diameter as to slide freely on the lower section, and with a strong flange on the top, with the cover recessed into it. I think this would be a cure for most of the trouble, except the plumber and the small boy, and I do not know of any remedy for them, except that a law be passed exporting the first and to curtail the propagation of the second.

EXPERIENCE PAPER.

BY CHARLES K. WALKER, SUPERINTENDENT, MANCHESTER, N. H.

[*Read Feb.* 10, 1897.]

My experience the past year has not been very pleasant. The trouble began in March, when high water carried off a bridge and the pipe which was laid on it, and which supplied the west side with water. About a thousand feet below this bridge there was a 12-inch pipe which had been laid across on the bed of the river and which was only used when repairs were being made on the line across the bridge. We turned the water on from this 12-inch pipe as soon as we could, but it took some time to find the gate, which was eight feet under water. It was quite a trick to find this gate and get the wrench on. You can imagine how I felt with the water shut off from 10,000 inhabitants and 165 hydrants. The newspapers came out the next day and said that we were lucky to have a pipe in the river as a reserve, but that the gate had been placed too low. I had found this out the day before. It takes a reporter to find out our mistakes after we have found them out ourselves.

I have been Superintendent of the Manchester Water Works for twenty-two years. When I first took charge there were twenty-three miles of pipe, which have since been increased to eighty-seven. We have used five different kinds of hydrants and five different kinds of gates and nearly every kind of meter. I would not recommend any of them; they will all go back on you sometimes. They are like a farmer's mowing machine; if they work well and cause no trouble, we are satisfied.

Meter rates you can never raise, so don't start with them too low. If it so happens that you have too much surplus you can reduce the rates, which is just, and the only right way; but as a rule you will need it. We have one way of doing business which works well: we take the money at the water office and deposit it in the hands of the City Treasurer, and he pays the bills. If there is anything that I would give you advice about without charge it is this: if you are lucky enough to have a surplus, look out and spend it for pipe, supplies, or

something else, for if there is any way that the city can get hold of it, they will use it for streets and sewers, or something besides water works. About five years ago we credited to the Manchester Water Works about $60,000. By some means they got the bars down and gobbled it up. You never can get the money back that is taken that way.

Another matter I will just mention. When the city of Manchester sells its water bonds, the city takes the premium which they bring and uses the money for other purposes and give us no credit. This is unfair.

Many of our service pipes were put in twenty years ago, and are filling up with rust. Cement-lined pipes laid before this time rust from the outside and are giving out. Tarred, enamel and rubber coated pipe are going to pieces. When the lead-lined pipe was first made, about six years ago, I began to use it, and am using it now. We lay inch pipe and run it to the street line.

We have had more trouble with fish getting into the connections than usual. We went fishing every day for about a month last summer. They go through the screens when quite small and grow in the distribution pipes. Nothing but the Lawrence filter would do them up.

I would say something about insurance companies if I dared to, but you know I got pounced on when I spoke of them once before. They want a big connection when they put sprinklers in the shops or mills and say that the water mains are too small. When I see a young man with a pencil behind his ear and a pressure gauge, trying hydrants in a mill yard, I know there is trouble ahead. By the way, did you ever know of a mill or shop stealing water from pipes put in for fire purposes only?

DISCUSSION.

Mr. Crandall. There is a six-inch meter in Burlington on one of our fire pipes, and I should judge that a great many people are inquiring as to the propriety of its present use. Whether the same thing is done in other cities and towns, I do not know.

Mr. Stacey. We do not have any meters on ours. It is right to have them on. I understand all about that, but we don't have them. My experience is that when you have a connection with a mill, they will beat you, if you do not have a meter; but if you make a man

who wants a plug pay for everything that goes through the meter, it is all right.

Mr. Roberts. In Fall River we do not put any meters on fire pipes on account of the objection of the insurance people. I think that that is the principal reason. We do not have any pipes for fire purposes only. A six-inch pipe is usually the size that we run in for mill protection, and we have no meters on such pipes, but we do meter the taps from such pipes supplying water for other purposes. I would like to know how it is in other cities.

Mr. Crandall. Some years ago I wrote to a number of parties on this matter. Mr. Kieran of Fall River was one of them, and I know that there were a number of places where pipes used for fire purposes only were being used for other purposes without paying the city therefor, and they did, in Philadelphia and other places, place meters upon pipes in order to prevent their use for other than fire purposes. In Burlington we have a fire service independent of any other purpose. If a party wishes a fire service he may have it free of charge, but he has no right to have the fire service for other purpose. If you allow a fire service to be used for other purposes, it is utterly impossible to tell how much water is used from it for other purposes.

AN INEXPENSIVE METHOD OF DETERMINING CHARGES FOR PUBLIC USE OF LARGE STREAMS, IN A MEASURE PROPORTIONATE TO THE AMOUNT OF WATER USED.

BY F. H. CRANDALL, C. E., SUPERINTENDENT, BURLINGTON, VT.

[*Read Feb.* 10, 1897.]

Where, in municipalities owning their water plant, the desirability of keeping the accounts of the different departments of public expenditure in such manner as to show the financial standing of each department with approximate accuracy is appreciated, it is often a matter of considerable difficulty to determine what is a fair valuation of the services rendered by the water department in furnishing water for various public uses.

The added force, which the cost of metering the services used for public purposes lends to the idea of the inutility of "transfers made from one pocket to another," as inter-departmental charges are sometimes called, tends to distract attention from the fact that the best means attainable should be taken to prevent the waste of the city's property, whether of water or other commodity.

The fact that the only way to interest the general public in the economical use of water is by making the matter one of personal, pecuniary interest is as true in the case of use for public as for private purposes.

So long as a lack of economy, not to say wasteful extravagance, on the part of an individual, or class of individuals, may take place without expense to them, there is no reason to expect them to practise economy, neither is there any reason to expect the average meter rate payer witnessing the extravagance of such a class to understand how the water which is of so little value that it is allowed to run constantly to waste from fixtures in schoolhouses, from park fountains, and from street sprinkling standpipes, can develop such value as it does when it runs for a short time to waste through his meter.

In the search for a method of determining inter-departmental charges for water. particularly those for water used for street sprink-

ling, which should be in a measure proportionate to the water used, and thus afford an incentive to the user to prevent waste, and at the same time avoid the expense of numerous large meters, we have, in Burlington, made some experiments in measuring a part only of the consumption.

It was thought that by the use of a small meter placed in a by-pass around a short contraction of the main line, for approximately the same use under approximately constant pressure, a nearly constant proportion of the consumption could be measured.

Our experiments have been duplicated under both seventy-five and one hundred and twenty pounds pressure and we have thus far been able to measure with a one-half inch meter placed in a by-pass around a short one and one half-inch reduction of a two-inch line within a fraction of one per cent of a constant proportion of the water used on streams from full capacity to one half inch in diameter.

Below the one-half inch stream the proportion measured grows less until on very small streams it is nothing. A check placed in that portion of the main line around which the by-pass is constructed serves the double purpose of causing a slightly larger proportion of the water used to be registered, and placing upon the party wasting the water the loss in case of small leaks. Further investigation with more carefully prepared appliances will very probably result in the measuring of a more constant proportion of the consumption.

Not the least of the advantages of such an arrangement over full size meter is the possibility of taking out the meter with scarcely any interruption of the supply, with none at all if it be deemed best to place stops on either side of the meter, and the utter impossibility of a failure to lay the dust for an afternoon being charged to the obstruction of the water supply by a meter.

The arrangement may be applied on large services supposed to be used at such infrequent intervals and for such purposes as not to warrant the expense of metering, for the purpose of determining the accuracy of the supposition.

In such cases a swing check with weighted lever handle, adjusted at such angle to the valve that the weight, which, when the valve is shut, causes small streams to take to the by-pass, will, when the valve is opened, be thrown off, is more effective and less objectionable as an obstruction of the water way, than an internally weighted check.

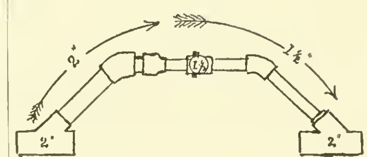
For use on a two-inch sprinkling standpipe an arrangement can be made with a few nipples and standard fittings, a one and one-half inch check and a half-inch meter, costing, exclusive of the meter, about six dollars, which will measure about seven per cent of the flow in streams from full size to one half inch in diameter with not more deviation from accuracy than that of the ordinary one-half inch meter multiplied by the constant used.

On the testing bench the constant factor to be used with the apparatus can readily be ascertained. In setting a meter in such a rigid line the advantage of a long thread and lock nut is apparent.

Whether these results, taking into account the advantages of first cost, cost of maintenance, and non-interruption of supply for care or repairs, the disadvantages resulting from the actual measurement of a part only of the consumption and the particular uses for which it is designed, are satisfactory or no, will be decided differently under different circumstances.

EXPERIMENTS WITH BY-PASSES.

Number.	Meter.	Percentage Metered. Full Capacity.		1 inch.	¾ in.	½ in.	Per cent diff'e betw. extremes.	Head lbs.	Check valve.	Description of Inlet.	Description of Outlet.
9	1″ T.	21.5	21.5	21 5	21.25	21.25	.25	75	1½″	3 bushings, smooth bell-shaped orifice.	3 bushings.
9	1″ T.	21.5	21.5	21.5	21.25	21.25	.25	75	1½″	3 bushings, smooth bell-shaped orifice.	3 bushings.
9	1″ T.	22	22	21.75	21.75	21.75	.25	120	1½″	3 bushings, smooth bell-shaped orifice.	3 bushings.
9	½″ N.	8.3	8.2	8.15	8.2	8.3	.15	75	1½″	5 bushings, smooth bell-shaped orifice.	5 bushings.
9	½″ N.	9.3	9.3	9.2	9.2	9.2	.10	120	1½″	5 bushings, smooth bell-shaped orifice.	5 bushings.
9	½″ N.	9.4	9.4	9.4	9.4	9.4	0	75	1½″	5 bushings.	5 bushings.
9	½″ N.	9.5	9.45	9.5	9.5	9.4	.05	120	1½″	5 bushings.	5 bushings.



RAPHIDOMONAS.

BY GEO. C. WHIPPLE, BIOLOGIST, BOSTON WATER WORKS.

A new organism has appeared to trouble the water works superintendent. Its name is Raphidomonas. It is an infusorian, a minute animal form. Unlike many infusoria it gives trouble not so much by producing a bad taste or odor as in the somewhat novel manner to be described.

The city of Lynn was the seat of the visitation which occurred about the middle of July, 1896. This city uses as its water supply four "ponds" or artificial reservoirs, namely Breeds, Birch, Walden, and Glen Lewis, the first two ordinarily furnishing water of good quality, the last two being at times badly afflicted with growths of micro-organisms. The first three ponds may be used independently or in combination. Glen Lewis Pond can be used only by drawing the water through Walden Pond. Pipe lines connect Birch and Breeds Pond directly with the pumping station. Walden Pond water reaches the pumping station by means of an open canal and a tunnel, leading to the upper end of Birch Pond and thence by a pipe line laid through the pond.

On Sunday, July 12, it was observed by some of the residents living in the western part of the city that the water drawn from the service taps had a decided green color. A glass of it when allowed to stand for even a few minutes showed a heavy green sediment. There was little taste other than that ordinarily present and due to the dissolved organic matter of the swamps. On the following day the water became worse; a thicker layer of "green stuff" was deposited in the tumblers. This caused comment but no alarm. Being Monday, however, the water was used for washing in the laundry and then trouble began. The water left green stains on the clothes, which acted similarly in every respect to grass stains. Boiling intensified them and soap seemed to make them even harder to remove.

A woman living on Hood Street told me about her experience as follows: —

"It was on a Monday. I went out where my daughter was wash-

ing, and as soon as I looked into the tubs I said, 'What makes your clothes look so dingy?' And then she took up a pillow sham which was in a clothes boiler and put it in the rinse and, would you believe it, it was all green like that [pointing to a leaf on a plant in the window]. I was so excited that I did not know what to do, for there was a new white dress in the bottom of the boiler. I pulled it out as soon as I could and found that it was worse than the other. It was green all over. My handkerchiefs were also green and the whole wash was spoiled. I sent one of the handkerchiefs to the Water Board office and the young lady there tried to wash out the green stains but she could n't. They acted just like grass stains. After working over the clothes for a long time and trying chloride of lime and other things I got most of the green out, but the clothes look kind of dingy yet. When I found that it was the water that did it, I boiled it before I used it. That made the green stuff settle worse, but I poured off the top and used that."

During the forenoon complaints began to be made at the central office. They did not come from the whole city, but chiefly from the section known as West Lynn, which is near the pumping station.

At this time water was being drawn from Breeds Pond and Walden Pond. The latter, because of previous offences, was at once suspected, and the water was accordingly shut off and Birch Pond water substituted. The trouble immediately disappeared, and it seemed certain that Walden Pond was guilty. In order to make sure of it, however, Superintendent Haskell caused samples to be collected from all the ponds and sent to the laboratory of the department where microscopical examinations were at once begun. Strangely enough, the samples showed nothing peculiar, even those from Walden Pond. This water contained a few colonies of Volvox globator, and a few green infusoria which in size resembled Phacus and which were so reported. These were the only organisms present which possessed a green color, and which could possibly account for the phenomenon — and their numbers were far too small to cause any trouble.

For this reason it was determined to try Walden Pond water again, but before doing so the writer, in company with the Superintendent, drove to the ponds and made a personal inspection. Samples collected from various parts of Walden Pond, near the dam and from different depths, were found to contain no abnormal growths

of organisms. We then turned our attention to the canal, and it did not take long to become convinced that this was the seat of the trouble. This canal through which all of the Walden Pond water must pass on its way to the city had its sides thickly coated with a growth of filamentous algæ — chiefly Cladophora. The water in the canal was of a dark green color, reminding one of a concentrated pea soup. A bottle of it when held to the light was almost opaque, and was seen to be densely crowded with moving, green particles, which proved to be the infusoria Raphidomonas. These organisms are rich in chlorophyll, and it was this chlorophyll that caused the "grass stains" on the clothes. Samples of the canal water were taken at various points and examined microscopically with the result that each cubic centimeter of water was found to contain from 1,200 to 2,000 Raphidomonas. They were thickest amongst the algæ where they appeared to find a very comfortable home. Doubtless they developed there and gradually scattered themselves out into the water as it passed through the canal. On the day of our visit, Walden Pond was not being used, and as the water in the canal was quiescent, the Raphidomonas had taken possession of everything.

Fortunately, the remedy was a simple one. The water in the canal was wasted through the waste-ways, and the sides and bottoms of the canal were thoroughly cleaned. After a few days, Walden Pond water was turned on again, and no further trouble was experienced. The canal was closely watched for some time thereafter, but no further development of Raphidomonas occurred.

Raphidomonas is not altogether unknown to science, although this is probably the first time that it has ever given trouble in a water supply. Like many other organisms, however, it has passed under a variety of names, each observer as he discovered some hitherto unknown characteristic thinking that this characteristic was sufficient to warrant the creation of a new genus, or else believing that his more accurate description deserved a re-christening. This multiplication of names, while it may be a mark of progress in knowledge, has caused a vast amount of confusion in all branches of natural history. Scientists have almost always taken greater pains to record differences among organisms than they have resemblances. Our Raphidomonas was probably first observed by Ehrenberg in some swamp near Berlin. He describes it under the name of *Monas semen* as follows : —

MONAS SEMEN (*Ehrenberg*).

"Body large, green, obovate, somewhat compressed, dilated and rounded anteriorly, attenuated posteriorly; a triangular cleft of the mouth at the forward end; many vibrating cilia. Length 1/48'''. Slow, vacillating movement. A central subglobose hyaline gland. Many green ovules. A contractile vacuole, and thin rod-like bodies visible. A narrow cleft observed extending from the mouth. Observed in January and February in decayed sphagnum in a swamp near Berlin."

Diesing in his "Revision der Prothelminthen" quotes Ehrenberg's description, adds a few words of his own, rearranges the matter, and changes the name to Gonyostomum. His description is given below. Whether Diesing himself saw the organisms or whether he bases his description wholly on Ehrenberg's account is unknown.

GONYOSTOMUM.

"Animalcules solitary, free swimming, symmetrical. Body obovate, unchangeable, green, not caudate, neither cilia nor lorica. Mouth on ventral surface, triangular, ciliated. No flagellum anus or eyespot. Inhabits fresh water.

"Spontaneous division unknown. Movement slow, vacillating, a central subglobose hyaline gland. Large green ovate bodies. A contractile vacuole and thin rod-like bodies visible. A narrow cleft extending from the mouth." (Ehrenberg.)

G. SEMEN (*Diesing.*)

"Body obovate, somewhat compressed, dilated and rounded anteriorly, attenuated posteriorly. Length 1/48'''. Habitat, in decayed sphagnum moss in a swamp near Berlin, January and February." (Ehrenberg.)

Stein in his magnificent work, published in 1878, gives a number of figures of our organism and these, with the index to the same, may be considered as the most accurate description up to the present time. These figures are shown on Plate No. 1. Stein gave to the organism the new generic name of Raphidomonas, but kept Ehrenberg's specific name semen, writing it thus, "Raphidomonas semen, (Ehr.) Stein." This was strictly in accord with etiquette as he took the generic name "Monas" given by the first observer and added to it a prefix which described one of its important characteristics. Bütschli has preferred to keep Diesing's name Gonyostomum. Later authorities have been somewhat evenly divided between the two. The present writer proposes to adhere to Raphidomonas semen, because of its appropriateness and because of its similarity to the

name given by the first discoverer, even though, as will be shown, Stein's description is faulty in one essential particular.

From Stein we learn that the animalcule is a free-swimming form having an elongate-ovate body, somewhat flexible, usually widest anteriorly, tapering posteriorly, and being generally two and one half to three times as long as wide, the length varying from 44 to 64 microns. The organism is monoflagellate, but a second flagellum has at times been observed. The oral aperture or mouth is placed at the anterior end and conducts into a conspicuous pharyngial chamber, triangular or lunate in shape, placed transversely. The contractile vescicle is conspicuous and anteriorly situated. The ovate nucleus is situated near the centre of the body. In some individuals there is a large "germ sphere" posteriorly located. The animalcule has a beautiful green color due to the presence of numerous large chlorophyll grains evenly distributed over the cuticular layer. Among these there are seen numerous rod-like or nettle-like bodies known as trichocysts, somewhat more numerous along the anterior margin than elsewhere over the surface. The organism moves somewhat sluggishly, but certain skipping movements are referred to.

The organisms seen by the writer are in most respects in accord with Stein's description. There is one very important difference however, namely: *they all have two flagella.* This feature is so constant that there is no doubt that Raphidomonas should be called bi-flagellate and not monoflagellate. Indeed, Stein himself alludes to the occasional presence of a "second flagellum directed backwards." It is perhaps not surprising that Stein should have overlooked the second flagellum because the microscopes of those days were inferior to those now in use, and because the second flagellum, and indeed sometimes both flagella, may easily be broken off by rough handling so that only a stump remains. This accident happened to a number of organisms which the writer recently sent through the mail.

The fact that Raphidomonas is a bi-flagellate infusorian is an important one when considering its place in a scientific classification.

Bütschli includes it (Gonyostomum) in the order Euglenoidea and the family Cœlomonadina, the other members of the family being Cœlomonas, Chromulina, Microglena, and Vacuolaria. In this connection it is interesting to note that Dr. A. C. Stokes has recently described a form which he has named Tentonia, which differs from

Raphidomonas only in the non-possession of trichocysts. It has two sub-equal flagella — one directed forwards and the other trailing.

The writer, not being an expert taxonomist, will not attempt to put Raphidomonas semen in its proper place, but wishes simply to call attention to its bi-flagellate nature.

The two flagella are approximately equal in length both being about half as long as the body of the organism and both issuing from the oral fossa. Both are vibratile, but one of them which is usually projected forwards, moves with a slow, deliberate, waving motion, while the second one, which is often coiled spirally near the body, but which is projected sometimes forward and sometimes backward, moves more rapidly with a coiling and twisting motion. It is probable that the sudden louse-like skipping movements of the organism are due to the rapid motions of this second flagellum.

The body of the organisms observed in the Lynn water were somewhat more obtuse than those figured by Stein. The length varied from fifty to seventy microns, averaging about sixty, and the breadth being generally about forty microns. These measurements were taken when the organisms were at rest. It was observed that when in motion the organisms lengthened out considerably, stretching forward, as it were, and instantly coming back to their normal shape when they stopped. Many abnormal forms were observed reminding one of the various shapes assumed by Euglena viridis. Raphidomonas from one or two other localities have corresponded more closely with the proportions of Stein's specimens.

The pharyngeal chamber has been described as triangular or lunate. This, on the whole, is a good description for the shape of the cavity when the organism is at rest. When in motion it becomes almost spherical. The contractile vesicle and the nucleus are quite conspicuous, the latter often being spherical rather than ovate, as depicted by Stein. The trichocysts, so far as I have observed, are quite uniformly distributed over the surface and are not more numerous at the anterior extremity than elsewhere. They are minute, dark-colored rods measuring five by one-half microns. Normally, they are arranged in a direction parallel to the axis of the organism. Their function is not known.

The chlorophyll grains, which make the organism an important one in the eyes of the sanitary biologist, are crowded closely together over the entire surface, giving to the organism a brilliant green color.

They are irregularly spherical and measure about three microns in diameter. On the breaking up of the organism the chlorophyll grains become scattered. Later, they themselves disintegrate, the chlorophyll becomes diffused, and minute oil globules are visible. The green coloring matter is readily soluble in ether, and, so far as observed, is in every way similar to the chlorophyll of plants.

In regard to the method of reproduction we know comparatively little. Stein speaks of a "germ sphere" as being present near the posterior extremity of some individuals, and Stokes affirms that his allied genus, Trentonia, reproduces by "encystment with subsequent binary fission." In this connection the following observations by the writer may be of interest, as they appear to indicate that reproduction takes place by sporular encystment.

It was frequently observed that if the Raphidomonas were allowed to stand for some time in a closed bottle, some individuals would disintegrate; others would lose some of their chlorophyll granules, and then become very compact, almost sperical in form. At the same time the "germ sphere" of Stein would become visible in the centre of the spherical mass. This would gradually take on a yellowish and then a dark brown color, and at the same time, oil globules would become visible in it. Later the chlorophyll granules would become diffused, other colorless round bodies would appear, and the brown colored matter in the "germ sphere" or sporocyst would collect in well-defined irregular masses. The escape of the sporocyst from the body of the organism and its subsequent rupture were not observed, but in the water were found many brown colored sub-spherical bodies which in size and color resembled the small masses in the sporocysts. These spheres were usually about four microns in diameter. They possessed a double cell wall. Whether they themselves subdivide is unknown, but, at any rate, several groups of smaller spheres were also observed.

Raphidomonas is negatively heliotropic. When allowed to stand in a bottle the organisms invariably move rapidly to that portion of the bottle farthest from the light, and, in seeking for them in a pond, they are usually found most abundantly in some shaded spot.

Raphidomonas has been found in other places besides the canal from Walden Pond. It was present in Walden Pond itself for some time before and after the episode of the green clothes, as will be seen from the following table: —

NUMBER OF STANDARD UNITS* OF RAPHIDOMONAS PER CUBIC CENTIMETER IN WALDEN POND, LYNN, MASS.

	Surface.	Bottom.
July 6, 1896	8	28
" 14, 1896	14	14
" 20, 1896	48	—
Aug. 3, 1896	24	18
" 10, 1896	42	48
" 17, 1896	120	52

It was also found about the same time in Birch and Breeds ponds, Lynn, but not in Glen Lewis Pond.

Soon after this, Mr. D. D. Jackson, assistant biologist of the Massachusetts State Board of Health wrote me that Raphidomonas was present in one of the Winchester reservoirs. Together we visited the spot and took a number of samples, finding the organisms in every one, but only in small numbers. More recently it has been seen in other surface waters in this State.

It seems more than probable that Raphidomonas is widely distributed in this region and that it is quite common in water supplies taken from ponds and artificial reservoirs. Everything points to the fact that its favorite habitat is the stagnant water of some swamp, where decaying vegetable matter is abundant. Recently in looking over the records of microscopical examinations made at the biological laboratory of the Boston Water Works the writer has been interested to note that Raphidomonas were present in the waters of Cedar Swamp Pond and of Whiteball Pond in the autumn of 1892. They were not abundant enough to make a complete study, and were recorded as "unidentified green infusoria." These same green infusoria, which were without doubt identical with Raphidomonas, have occasionally been seen in other portions of the Boston Water supply. Moreover, it seems probable that the organism has sometimes been recorded as Phacus, which it resembles somewhat in size and color.

In conclusion, the writer desires to express his obligations to Dr. A. C. Stokes, who kindly examined some of the living specimens, and to Mr. Gary N. Calkins, of the Department of Zoölogy of Columbia University, who has reviewed the descriptions and who

---

*One standard unit equals 400 sq. microns.

endorses the position taken regarding the name, Raphidomonas semen (Ehr.) Stein-Whipple.

Literature.

1. *Ehrenberg, Chr. G.* "Ueber die neuerlich bei Berlin vorgekommenen neuen Formen des mikroskopischen Lebens." Monatsberichte der Berlin Akad, 1853, pp. 189–194.

2. *Diesing, K. M.* "Revision der Prothelminthen." Sitzbungberichte der math. nat. Kl. d. Akad. zu Wien, Bd. LII., 1866, pp. 287–402.

3. *Stein, Dr. Ritter von.* "Der Organismus der Infusionthiere, III., Der Organismus der Flagellaten oder Geisselinfusorien." 1 Halfte. Leipzig, 1878.

4. *Bütschli, Dr. O.* "Klassen und Ordungen des Thier-Reichs." II., Abtheilung, p. 819, Leipsig und Heidelberg, 1883–87.

5. *Kent, W. Saville.* "A Manual of the Infusoria." Vol. I., p. 391, London. 1880–81.

6. *Eyferth, B.* "Die Einfachsten Lebensformen des Thier- und Pflanzenreiches." P. 61, Braunschweig, 1885.

7. *Blochmann, Dr. Friedrich.* "Die Mikroskopische Thierwelt des Susswassers." Theil II., p. 35.

8. *Lancaster, E. R.* "Protozoa" in Enc. Brit.

9. *Stokes, Dr. A. C.* "A Preliminary Contribution towards a History of the Fresh Water Infusoria of the United States." Jour. of the Trenton Nat. His. Soc., Jan., 1888, Vol. 1, No. 3, p. 125.

DISCUSSION.

Mr. Jackson. In connection with Mr. Whipple's paper, I would like to state I have seen the organism of which he speaks in quite a number of places throughout the State. It seems to be quite widely distributed, but it is more noticeable in Lynn, Walden Pond, and in the middle reservoir at Winchester. The organism must be present in very large numbers to cause green stains in the laundry. Small numbers of all these detrimental organisms occur throughout the State in various water supplies, and give no trouble whatever.

RAPHIDOMONAS.

QUARTERLY MEETING.

Young's Hotel,
Boston, March 10, 1897.

President Haskell in the chair.

The following members and guests were present: —

Active Members.

Everett L. Abbott, Solon M. Allis, R. S. Bartlett, E. C. Brooks, E. W. Bailey, Charles H. Baldwin, Everett Barns, Albert P. Barrett, George H. Barrus, George E. Batchelder, Oren B. Bates, Joseph E. Beals, Nathan B. Bickford, James F. Bigelow, George Bowers, Dexter Brackett, Arthur W. F. Brown, John T. Cavanaugh, George F. Chace, E. J. Chadbourne, Charles E. Chandler, John C. Chase, Harry W. Clark, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, Lorin N. Farnum, B. R. Felton, F. F. Forbes, Frank L. Fuller, Julius C. Gilbert, Albert S. Glover, W. J. Goldthwait, Frederick W. Gow, E. H. Gowing, John C. Haskell, L. M. Hastings, Louis E. Hawes, T. G. Hazard, Jr., Allen Hazen, John S. Hodgson, Horace G. Holden, Horatio N. Hyde, Daniel D. Jackson, Willard Kent, Patrick Kieran, Frank C. Kimball, George A. Kimball, Morris Knowles, James W. Locke, Thomas C. Lovell, James L. Lusk, James W. Morse, Charles F. Murphy, H. A. Nash, Jr., Thomas Naylor, Edward C. Nichols, Frank L. Northrop, Horatio N. Parker, Walter H. Richards, George J. Ries, Daniel Russell, F. J. Shepard, Melville A. Sinclair, Solon F. Smith, H. T. Sparks, George A. Stacy, Lucian A. Taylor, Joseph G. Tenney, Robert J. Thomas, William H. Thomas, D. N. Tower, D. W. Tenney, W. H. Vaughan, Charles K. Walker, J. Alferd Welch, Elbert Wheeler, William Wheeler, George C. Whipple, John C. Whitney, George E. Winslow, E. T. Wiswall.

Honorary Members.

"The Engineering Record," by C. J. Underwood.
"Fire and Water," by F. W. Shepperd.

Associate Members.

Chapman Valve Manufacturing Company, by E. L. Ross.
Coffin Valve Company, by A. A. Blossom.
Deane Steam Pump Company, by Messrs. Hayes, Pierce & Richardson.
M. J. Drummond, by W. F. Briggs.
George E. Gilchrist, by F. N. Stebbins.
Henry F. Jenks.

Ludlow Valve Manufacturing Company, by H. F. Gould.
National Meter Company, by J. G. Lufkin.
Perrin, Seamans & Co., by H. L. Bond.
Rensselaer Manufacturing Company, by F. S. Bates.
R. A. Robertson.
Anthony P. Smith, by W. H. Van Winkle.
Benjamin C. Smith, by F. A. Smith.
Union Water Meter Company, by J. P. K. Otis.
R. D. Wood & Co., by Jesse Garrett.
The Edward P. Allis Co.

GUESTS.

Peter Milne, Chief Engineer, Brooklyn, N. Y.; F. L. Weaver, Water Commissioner, Lowell, Mass.; L. H. Jones, Water Commissioner, Lowell, Mass.; J. G. DeMello, Foreman, New Bedford, Mass.; J. J. Moore, Boston, Mass.; F. W. Reynolds, Boston, Mass.; Thomas Rogers, Pumping Engineer, Nashua, N. H.; A. W. Barnes, Fitchburg, Mass.; F. Strout, Pumping Engineer, Reading, Mass.; Edwin Kieran, Weymouth, Mass.; Robert Mitchell, Weymouth, Mass.; J. J. Stockton, Bangor, Me.; H. B. Tower, Cohasset, Mass.; Mr. Pratt, Mr. Riley, Mr. McCarty, and Mr. Dwyer of Marlboro, Mass.; Mr. Killam, Brockton, Mass.; Mr. Groce, Dr. Hurlburt Hill, Mr. R. S. Weston.

The Secretary read the names of the following applicants for membership, recommended by the Executive Committee: —

RESIDENT ACTIVE.

George L. Chapin, Commissioner, Lincoln, Mass.
Horatio N. Parker, Assistant Biologist, Western Division, Boston Water Works.

NON-RESIDENT ACTIVE.

Morris Sherrerd, Newark, N. J., Engineer Newark Water Department.
Charles Comstock Hopkins, Rome, N. Y., Stanwix Engineering Co.
Charles W. Knight, Rome, N. Y., Stanwix Engineering Co.

On motion of Mr. Coggeshall, the Secretary was directed to cast the ballot of the association for the candidates, and they were declared elected.

The President announced that the Executive Committee had decided that the June meeting of the association would be made the occasion of a visit to the Metropolitan Water Works at Clinton; and that the annual meeting of the association would be held at Newport, R. I., beginning on the second Wednesday in September.

The President then called upon Mr. Peter Milne of Brooklyn, Sec-

retary of the American Water Works Association, who was received with applause, and spoke as follows:

Mr. Milne. Mr. Chairman and gentlemen of the New England Water Works Association, I thank you for your kind reception. I am glad to meet you here in a fraternal spirit. I do not feel like trespassing upon the time which is assigned for other and more important work. I can only say that your manifestation of kindness expressed to me to-day, I will take and transmit as the Secretary of the American Water Works Association. I am here in an official capacity for the city of Brooklyn, and I feel as if I were one of this family, that the men here are almost brothers to me, even if I know them not by name. I have been long enough in water works practice to realize the trials and experiences of officials in water works administration. I have noted with great satisfaction the progress and development of the New England Water Works Association, and it is no small degree of honor to you, gentlemen, that you have contributed out of your organization a great deal to the material welfare of the communities which you represent, and have done much to develop water works practice throughout New England and the country. You may well believe and congratulate yourselves that individually and collectively you have in no small degree contributed to promote the efficiency of water works practice. Your literature is sought for and is now deposited in the archives of the most important libraries of the country pertaining to our profession. [*Applause.*]

Mr. William Wheeler, of Boston, presented a paper describing the "Covered Filters at Ashland, Wis."

Mr. Lewis M. Bancroft submitted a paper, which was read by Mr. Hazen, on "The Iron Removal Plant at Reading, Mass."

Mr. George C. Whipple, Biologist of the Boston Water Works, read a paper on "Raphidomonas."

Adjourned.

JOURNAL

OF THE

New England Water Works

ASSOCIATION.

VOLUME XII.

September, 1897, to June, 1898.

PUBLISHED BY

BOARD OF EDITORS.

Junior Editor's Office, New London, Conn.

INDEX.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XII. September, 1897. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME OBSERVATIONS ON THE GROWTH OF ORGANISMS IN WATER PIPES.

BY GEORGE C. WHIPPLE, BIOLOGIST, AND DIRECTOR OF MOUNT PROSPECT LABORATORY, BROOKLYN WATER DEPARTMENT.

[*Read Sept.* 8, 1897.]

The reactions between the water and the water pipes of any water works system are topics of vital importance. They involve such matters as iron rusting, tuberculations, lead poisoning, and others, all of which have been the subject of much study, and some of which are even now but imperfectly understood. Up to the present time, it has been the chemical and physical reactions that have received attention. There is, however, a sort of biological reaction between the water and its conductors which is not unworthy of our consideration.

The question may be approached from two sides. In fact, there are two questions, namely: What effect have the aqueducts and pipes upon the biology of the water, and what effect has the water upon the biology of the aqueducts and pipes? There is comparatively little accurate data to be obtained upon these questions, and as the extensive biological observations of the Boston Water Works, now covering a period of eight years, offer the greatest amount of available material,* they will be used as the basis of the discussion.

*Annual Reports of the Boston Water Works, 1891 to 1895.

It is unnecessary to describe this water supply to the members of this Association, but for the sake of those not familiar with it, it may be well to state that there are two different sources, Lake Cochituate and the Sudbury River. Both are surface waters. The former is a chain of lakes, four miles in length and of considerable depth, that furnishes water light in color, at times rich in microscopical organisms, and containing moderate numbers of bacteria. This is conveyed through a brick-lined aqueduct to the distributing reservoirs at Chestnut Hill and Brookline. The Sudbury River, utilized by the construction of several storage reservoirs, or basins, furnishes a water of rather high color, and one that contains an abundance of organic matter. This water also is conveyed to the Chestnut Hill and Brookline reservoirs, where it mixes with the Cochituate water. From these reservoirs the mixed waters are carried to the city through several lines of 48-inch and 36-inch pipes.

It was the custom, for a number of years, to collect weekly samples of water for analysis at the effluent gate houses of these two reservoirs, at a tap in Park Square, Boston, and at a tap in Mattapan. Occasional samples were taken at other places in the city. The object was to determine the difference in the character of the water in the different sections of the city, and to ascertain what changes took place in the water during its passage through the pipes. The tap in Park Square is about five miles from the Chestnut Hill reservoir, and the tap in Mattapan about eleven miles. Examination of the pipe lines, and a study of the color of the water, show that in all probability the Park Square tap is supplied with water direct from the Chestnut Hill reservoir, while at Mattapan the water comes largely from the Brookline reservoir. This is largely a matter of assumption, however, and as the Superintendent has always taken great pains to keep the mixture of Sudbury and Cochituate water the same in both reservoirs, it matters little for the purposes of this paper whether the water comes from the one or the other. Hence we may say that the chief difference between the two tap samples lies in the different lengths of pipe through which the water passes. It should be borne in mind, however, that as the water flows from the reservoirs to the outer limits of the distribution system, the sizes of the pipes diminish, so that the Mattapan water passes through a greater length of pipe of small size than the water at Park Square.

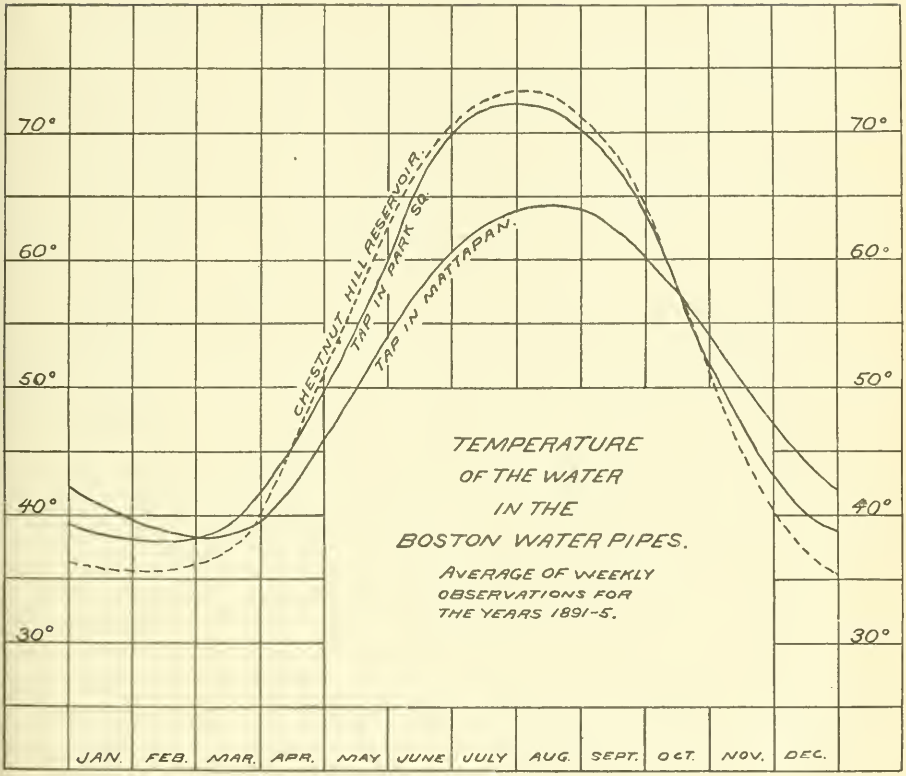


PLATE I.

The temperature of the water at the effluent gate house at Chestnut Hill reservoir, and at the taps mentioned, is shown on Plate I, where the curves represent the averages of weekly observations for five years (1891 to 1895). As would be expected, the greatest range of temperature occurs in the reservoir, though the water in the tap in Park Square agrees with it closely. The effect of the passage of the water through the pipes is well shown by the curves. During the spring and summer the water grows cooler, and during the fall and winter it grows warmer as it passes through the ground. In the summer the water is always several degrees cooler at Mattapan than at Park Square, the greatest difference being observed during July and August. In the winter the minimum temperature at the two taps is about the same, but at Park Square the lowest

point is reached in February, while at Mattapan it is found one month later. A comparison of the mean monthly temperatures for each year is given in Table I.

If we consider the results of the biological examinations, as published in the annual reports of the Boston Water Works, we shall find that for the five years from 1891 to 1895, the microscopical organisms and amorphous matter were present, as follows:

	Number of Standard Units per c. c.	
	Organisms.	Amorphous Matter.
Chestnut Hill reservoir, gate house	248	209
Brookline reservoir, gate house	215	212
Tap in Park Square	194	190
Tap in Mattapan	84	105

If we assume that the water at the Park Square tap comes from the Chestnut Hill reservoir, and that at the Mattapan tap from Brookline reservoir, we shall find that during its passage from Chestnut Hill reservoir to Park Square the water lost 22 per cent. of its organisms and 9 per cent. of its amorphous matter; while from Brookline reservoir to Mattapan it lost 61 per cent. of its organisms and 50 per cent. of its amorphous matter. If we assume that both taps receive the mixed water from both reservoirs, we find that during its passage through about five miles of pipes the water lost 16 per cent. of its organisms and 10 per cent. of its amorphous matter; and through eight miles of pipe, 64 per cent. of its organisms and 50 per cent. of its amorphous matter. The greater part of the reduction is seen to occur not near the reservoirs where the pipes are large and the currents great, but in the extremities of the distribution system, where the pipes are smaller. It will be sufficient and somewhat simpler to consider only the two taps.

Tables II. and III. show the number of microscopical organisms and the amount of amorphous matter in the water at Park Square and Mattapan for each month during a period of five years. The figures are based on weekly examinations. The averages for the whole period are given in the last two columns. The latter are also shown graphically on Plate II. Study of the plate and tables shows that during the winter, when there are comparatively few organisms in the water, the reduction in the pipes is much less than during the summer, when organisms are more abundant. We find by

calculation that during the six months of the year, from November to April, there is a reduction of 44 per cent. in organisms and 24 per cent. in amorphous matter in passing through about six miles of pipe; while during the six months from May to October the reduction is 62 per cent. for the organisms and 53 per cent. for the amorphous matter. It is interesting to note that the reduction in organisms is greater than the reduction in amorphous matter.

Not only are the microscopical organisms and amorphous matter reduced in the pipes, but the bacteria also tend to decrease. This fact has been observed several times in other cities. The figures presented in Table IV. show that in the pipes of the Boston Water Works the decrease does not occur throughout the entire year. In the summer, when the temperature of the water is high and when the organisms in the water and those growing in the pipes are passing rapidly through stages of growth and decay, there is a considerable increase. This is seen best by the aid of the diagram (Plate II.). That it is no accidental observation is shown by the fact that it occurs regularly each year, and that the same results were obtained whether the samples were plated at the time of collection or after transportation to the laboratory.

In order to determine what organisms showed the greatest reduction in the pipes, a more detailed study of the examinations was made for the years 1892 and 1893. The following were the results:

Percentage Reduction of Microscopical Organisms in the Distribution Pipes Between Park Square and Mattapan.

	Average for the years 1892 and 1893.
Diatomaceæ	58 per cent.
Chlorophyceæ	57 " "
Cyanophyceæ	54 " "
Infusoria	64 " "
Miscellaneous	58 " "
Organisms of all kinds	56 " "

It appears that the infusoria are reduced the most and the cyanophyceæ the least. The difference between the two is slight, however.

Examinations of the Mystic water supply at College Hill reservoir and at a tap in Chelsea also show a reduction in organisms and amorphous matter during the passage of the water through the

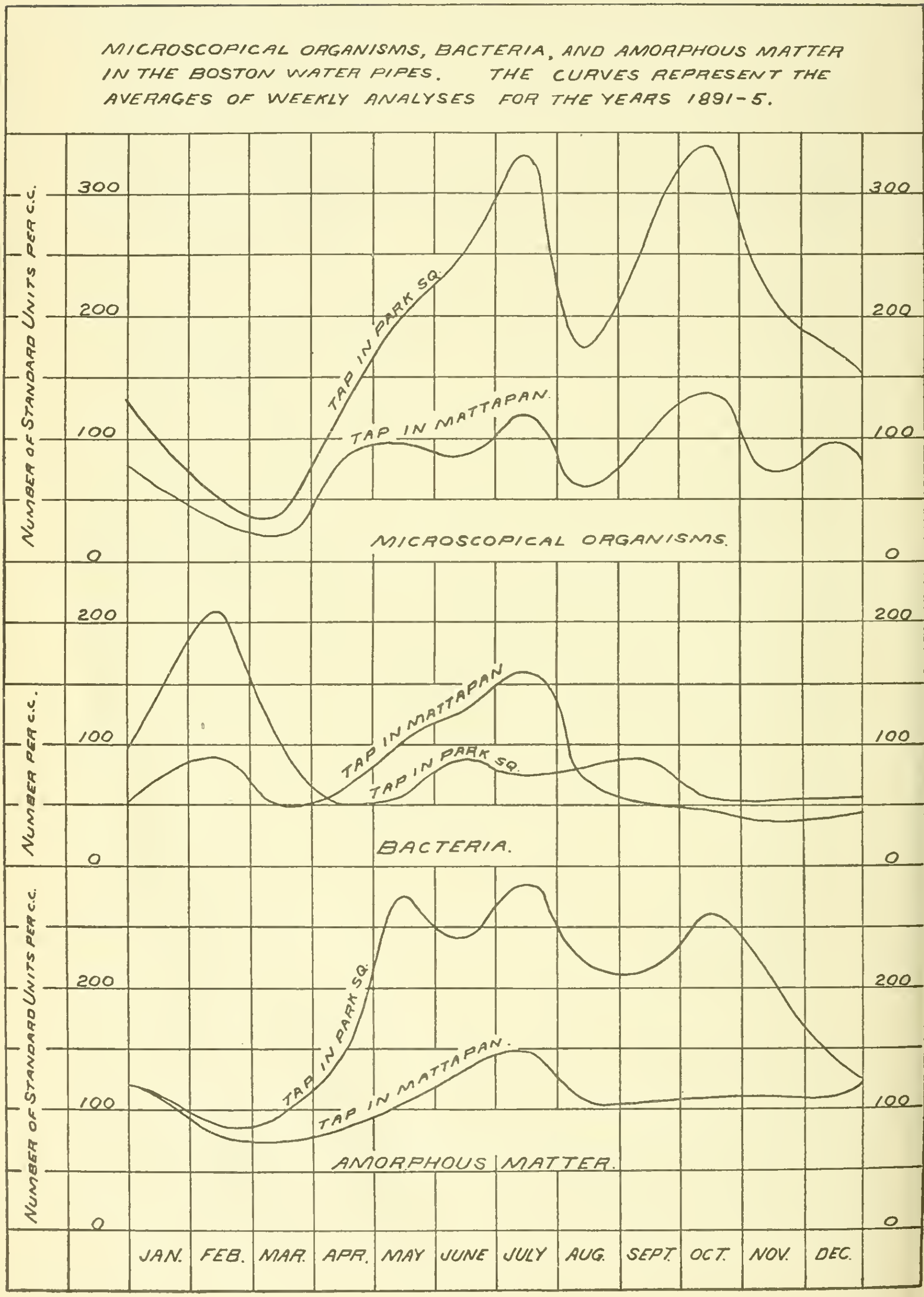

MICROSCOPICAL ORGANISMS, BACTERIA, AND AMORPHOUS MATTER IN THE BOSTON WATER PIPES. THE CURVES REPRESENT THE AVERAGES OF WEEKLY ANALYSES FOR THE YEARS 1891-5.
NUMBER OF STANDARD UNITS PER C.C.
300
200
100
0
TAP IN PARK SQ.
TAP IN MATTAPAN.
MICROSCOPICAL ORGANISMS.
NUMBER PER C.C.
200
100
0
TAP IN MATTAPAN
TAP IN PARK SQ.
BACTERIA.
NUMBER OF STANDARD UNITS PER C.C.
200
100
0
TAP IN PARK SQ.
TAP IN MATTAPAN.
AMORPHOUS MATTER.
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

PLATE II.

pipes. Table V, which represents the results of monthly examinations for four years, shows that the average reduction of organisms was 41 per cent. and of amorphous matter, 52 per cent.. The bacteria were usually lower at the tap, but occasionally an increase in the pipes was noticed.

Questions naturally arise as to the cause and effect of this reduction of organisms in the pipes. We may consider them under the following topics: sedimentation, disintegration, decomposition, and consumption by other organisms.

Most, and probably all, of the microscopical organisms are heavier than water. Some always settle in quiet water, and they do so in the pipes whenever the current is reduced to a certain point. Others, which in ponds usually rise to the surface on account of the gas bubbles which they contain, will settle in the pipes when the pressure of the water has deprived them of their gas. In dead ends the organisms and particles of amorphous matter often accumulate and form deposits upon the bottom of the pipes. They also tend to deposit on up-grades. It is a matter of frequent observation that the water from the high points of a distribution system contains fewer organisms than that from the low points. The same fact has been observed in high buildings, where the difference between the water on the upper stories and that on the lower floor is often considerable.

Many of the common organisms are very fragile. Even a slight agitation of the water will break them up. This is particularly true of certain infusoria. It is easy to understand, then, how the subjection to the pressure and the currents of a distribution system causes them to go to pieces. No better example can be found than the Uroglena. A cluster of delicate organisms, embedded in a gelatinous material, upon the outer surface of a sphere, it is one of the most fragile organisms imaginable. A slight pressure or agitation will rupture the colony, and scatter and disintegrate the individuals. In the epidemics of Uroglena that have afflicted so many of our New England ponds, it has been found almost invariably that the Uroglena were abundant in the water of the reservoir, but not in the tap water. By their disintegration the oil globules, which are the cause of the vile fishy odor, are liberated, with the result that the water at the tap almost always smells and tastes worse than the water at the source. This disintegration, with

liberation of oil globules, occurs to some extent in organisms that could hardly be called fragile. The diatoms, which have siliceous cell walls, sometimes go to pieces in the pipes, causing an increase in the odor of the water. This was observed in the recent epidemic of Asterionella in Brooklyn, N. Y.

The organisms found in surface waters are accustomed to live in the light. When they enter the dark pipes they are liable to die and decompose. This is particularly true of some of the organisms that are abundant in the summer. Microscopical examination of samples from the service taps have often revealed organisms in a decomposing condition, swarming with bacteria. This decomposition tends to reduce the numbers of organisms in the pipes.

Another important consideration in the reduction of organisms is the fact that in many of the distribution systems where surface waters are used the pipes are covered with growths of sponge, etc. These attached growths depend for their food material upon the minute organisms found in the water. If the growths are abundant, the removal of organisms from the water from this cause may be considerable. This naturally brings us to our second topic,—the growth of organisms in the pipes.

Comparatively little has been written about the subject in this country. Our attention has been called to growths of Crenothrix and of Fresh Water Sponge, but no attempt has been made to give an accurate account of the organisms infesting the distribution systems of our water supplies. In Europe, however, we find that the subject has been considered to some extent.

In the city of Hamburg the "Minute animals inhabiting water pipes were studied by Hartwig Petersen* in 1876. Ten years later Karl Kraepelin† made a more extended study. His observations are of much interest. He found an animal growth, often more than one centimetre thick, covering the entire surface of the pipes. The composition of this growth varied in different places. He gives a list of sixty different species observed. In many places the walls of the pipes were covered with fresh water sponges, chiefly Spongilla fluviatilis and S. lacustris. Mollusks were conspicuous, especially

*Hartwig Petersen, "Die Bewohner der Hamburger Wasser-leitung," in Vehandl. d. Vereins f. Natur. Unterhaltung. II. Bd., Hamburg, 1876.

†Karl Kraepelin, "Die Fauna der Hamburger Wasser-leitung," Abhandl. d. Naturw. Vereins in Hamburg. IX. Bd., Heft. I., 1886.

the mussel Dreyssena polymorpha. Snails were also numerous. Hundreds of "water lice" (Asellus aquaticus) and "water crabs" (Gammarus pulex) were found at every examination. The material known as "Pipe moss" was common, and consisted largely of Cordylophora lacustris and the Bryozoa Plumatella and Paludicella.

At the time when Crenothrix was giving so much trouble at Rotterdam, Hugo de Vries* made an extended study of the animals and plants found in the water pipes of that city. His observations were confined chiefly to the pipes and canals which conveyed the unfiltered water of the River Maas to the filter beds. In speaking of one of the canals he says, "The walls were thickly covered with living organisms up to the water level. They formed an almost continuous coating of changing composition. There were only one or two exceptions to this. In one place, where the water came from the pumps with great velocity, the walls were free from living organisms; and in another place, where there was almost no current, only one living form was seen. There was one section of one of the canals, where a gentle current was flowing, that was a magnificent aquarium. The walls were everywhere covered with white tufts of fresh water sponge (Spongilla fluviatilis.) Many of these tufts reached a diameter of six or eight inches, but most were somewhat smaller than that. Between the sponge patches were seated countless numbers of the mussel Dreyssena polymorpha. Individuals old and young were often seen grouped together in colonies which sometimes extended completely over the sponges. But what most of all attracted attention was a luxurious growth of the "Horn-polyp," Cordylophora lacustris. It covered the mussel shells and occupied all the space between the sponges. The stalks reached a length of an inch or more. On and between the Cordylophora swarmed countless numbers of Vorticella, Acineta, and other infusoria and rotifers. These organisms had no lack of food material and the absence of light protected them from many foes which, in the light, thin out their ranks. Over all these animals Crenothrix was found growing in abundance. The shells of the mussels and the stems of the "Horn-polyps" were coated with a thick felt-like layer of these iron bacteria." In other localities in the pipes the place of the

*Hugo de Vries, "Die Pflanzen und Thiere in dem dunkelln Raumen der Rotterdamer Wasser-leitung." Jena, 1890.

"Horn-polyps was occupied by the Bryozoa, or "Moss animalcules." All of these branching forms were spoken of collectively by the workmen as "Pipe moss."

In the summer of 1896, when the pipes of the Metropolitan Water Works were being laid in Beacon street, near the Chestnut Hill reservoir, a 16-inch main leading from the Fisher Hill reservoir to the Brighton district was opened. This afforded an opportunity to examine the material on the inside of a pipe that had been laid ten years. Inspection showed that besides the usual coating of iron rust, tubercles, etc., there were numerous patches of fresh water sponge (both Spongilla and Meyenia), brownish or almost white in color, and about the size of the palm of one's hand. What was most conspicuous, however, was a sort of brown matting which covered much larger areas, and which had a thickness of about ¼ inch. It had a very rough surface and, when dried, reminded one of a piece of coarse burlap. This proved to be an animal form belonging to the Polyzoa, and known as Fredericella. As fragments of it had several times before been observed in the water from the service taps, and as it had been seen growing in some small pipes connected with the filtration experiments at Chestnut Hill reservoir, more extended observations were made in different parts of the distribution system.

These brought out the fact that sponges and Polyzoa are well established in the pipes. Many other kinds of organisms were also observed. In some places almost pure cultures of Stentor and Zoothamnium were found. At other points hosts of different organisms were seen, such as snails. mussels, Hydra, Nais and Anguillula, Acineta, Vorticella, countless numbers of ciliated infusoria; Arcella, Amœba, and many other forms. The growths were distinctly animal in their nature, though in many cases parasitic vegetable forms such as Achlya, Crenothrix, Leptothrix, etc., were common. The most important class of organisms, however, was the Polyzoa, of which Fredericella and Plumatella were the chief representatives.

The Polyzoa, or the Bryozoa as they are usually called on the continent, are animals that in some respects resemble the hydra-like polyps. They form colonies that sometimes extend to enormous proportions, hence the appropriateness of their name "Polyzoa," which means "many animals." In the adult stage they lead a sedentary life, firmly attached to some submerged object. The animals

themselves are small, but easily visible to the naked eye. Some of them are covered with a secreted coating, or sheath, that takes the form of narrow, brown-colored tubes; others are imbedded in a mass of jelly. The genera that live in the brown, horny tubes, are the ones that most interest us. They form tree-like growths that often attain considerable length. The branches of the little trees are sometimes an inch long, and each one is the home of an individual polyzoon, or polypide. The branches, or hollow twigs, are separated from the main stalk by partitions, so that, to a certain extent, each polypide lives a separate existence in its own little case, though each was formed from its next lower neighbor by a process of budding. The horny covering is formed of a chemical substance allied to chitin, though in some genera it is calcareous.

The most conspicuous part of the animal is always the circlet of ciliated tentacles. They are mounted on a sort of platform, or disc, called a lophophore, at the forward end of the body. This lophophore, with its crown of tentacles, may be protruded from the end of its protective tube at the will of the animal. The tentacles themselves may be expanded, giving a beautiful, bell-shaped, flower-like appearance. They are hollow, and are covered with fine hair-like processes, or cilia. They are also muscular, and can be bent and straightened at will. By their combined action, powerful currents in the water are set up towards the mouth of the animal, which is situated just beneath the lophophore. Minute organisms are thus swept in as food. In some genera the food material may be watched in its progress through the alimentary canal, but in the animals that dwell in the horny tubes we can only see it disappear into the tube. The animals when disturbed have the power of instantly retracting their tentacles, and this sudden retraction, together with the sly and cautious way in which they afterwards extend them, have long since made the Polyzoa objects of great interest to students of the microscope.

The number and arrangement of the tentacles vary in different genera. In Paludicella, for example, they are 16 in number, arranged in a circle; in Fredericella there are 24, arranged in a sort of oval; while in Plumatella they are much more numerous, and are arranged in a double row in the shape of a crescent or horseshoe.

The body of the organism is a transparent membranous sack, immersed in the jelly or concealed in the brown opaque sheath. It

contains a U-shaped alimentary canal, with a contractile oesophagus, stomach, and intestine; a muscular system that permits some motion within the case, and that causes the extension and contraction of the tentacles; mesentaries in the form of fibrous bands; an ovary, and a rudimentary nervous system. There is no heart nor blood vessels of any kind.

The Polyzoa increase by a process of budding which gives rise to the branched stalks, as we have before remarked. There is also sexual reproduction. In old colonies, especially late in the season, there are often seen small, rounded brown bodies, which, as the animals die, float to the surface of the water. They are the winter eggs, or statoblasts. They are formed within the body, and escape only when the Polyzoon dies, when they emerge. and remain unchanged until the warmth of spring develops them. These statoblasts vary in shape in the different genera and are a valuable aid in identifying species.

The favorite habitat of the Polyzoa is some pond or gently flowing stream where microscopical organisms are plenty. They are often found on the under side of some old board or log. They were once seen covering the entire wood-work of an old dam. They choose shady spots, as a rule, though occasionally they are found in the full glare of sunlight.

They are often found in our water supplies, in the ponds, reservoirs, aqueducts and pipe lines. Boston is by no means the only city where they are met with. They have been observed in many other cities both in New England and elsewhere. Potts speaks of them as being found in the gate houses of the Philadelphia supply, and we have previously referred to their presence abroad. The branching forms seem to be the most important, but the jelly forms are not uncommon. Potts* found the Pectinatella in Fairmount reservoir, Philadelphia, and Crystatella has been often noticed in some of our New England supplies. Perhaps the most notable case of the latter occurred recently in Cape Pond, the water supply of Rockport, Mass. It developed there in great quantities, and was especially abundant on the wood-work at the mouth of the suction pipe. It caused more or less trouble by fouling the sides of the

*E. Potts, "On the Minute Fauna of Fairmont Reservoir," Proc. Acad. Nat. sci., Philadelphia, 1884, pp. 217-219.

stand-pipe, and threatened to become a serious nuisance. The jelly secreting Polyzoa, so far as I am aware, have never been actually observed in the pipes of any water supply.

The fact that the organisms that dwell in water pipes depend for their food material upon the algæ, infusoria, etc., contained in the water, may be easily demonstrated by experiment. Specimens of Fredericella and Plumatella were once placed in a series of jars, some of which were supplied with water rich in its microscopic contents, while others were supplied with the same water after filtration. All the jars were kept in semi-darkness at the same temperature, and were examined daily. The Fredericella and Plumatella that had been supplied with filtered water soon began to die, while those in the other jars lived as long as the experiment was continued. Some of the same Polyzoa were placed in jars furnished with water from the Newton supply, and after about a week they died for want of food. This agrees with what I have learned from the officials of the Newton and Brookline Water Works, that in the distribution pipes of those places such organisms as sponges and Polyzoa are never found. Both supplies are ground water. Dr. G. H. Parker* once made a similar experiment on fresh water sponge, and obtained the same result.

With these facts established, we may confidently affirm that fresh water sponge, Polyzoa, and similar pipe-dwellers will be absent from water pipes where ground water, or water that has been effectively filtered, is used.

One naturally asks, "What is the effect of these organisms growing in the pipes?" In a certain sense they tend to improve the quality of the water by reducing the number of floating microscopical organisms; but they themselves must in time decay, and anyone whose nose has ever had an experience with decomposing sponge will appreciate the fact that better places for these organisms may be found than the distribution systems of our water supplies. It should be stated, however, that in all probability very large quantities would be required in order to produce tastes or odors that would be noticed in the water. No authentic case of trouble from

*G. H. Parker, Experiments on Fresh Water Sponge, Special Report of the Mass. St. Bd. of Health, 1890, p. 618.

this cause has been thus far recorded, so far as I am aware. Perhaps the greatest objection to their presence, is the fact that they tend to impede the flow of water in the pipes. When one considers that a coating $\frac{1}{4}$ inch thick diminishes the area of the cross-section of a 24-inch pipe by 4 per cent, and of a 6-inch pipe by 15 per cent, and when one learns that these organisms often form layers even thicker than this, it will be seen that such growths are matters of no little importance. Furthermore, fingers of the fresh water sponge sometimes extend several inches into the water, and the matting of the Polyzoa is always rough on account of the stiff branches that are extended into the water in order that the organisms may secure their food. This roughness of the surface must increase the friction of the pipe by an indefinite, but considerable amount.

Summing up the results of these few observations, we learn:

That during the passage of a surface water through the pipes of a distribution system there is ordinarily a considerable reduction in the number of organisms, due to sedimentation, disintegration, decomposition, and consumption by other organisms.

That there is a similar decrease in the number of bacteria, except during those periods of the year when decomposition is going on in the pipes.

That growths of fresh water sponge, Polyzoa, etc., are liable to occur in the distribution pipes of any surface water supply.

That these growths tend to reduce the capacity of the pipes, by diminishing the area of the cross-section and by increasing the friction.

That by their decay, they tend to the production of bad tastes and odors, though it is probable that very large amounts are necessary to give serious trouble.

That these growths of sponge, "pipe-moss," etc., depend upon the minute organisms in the water for their food supply, and that they will die when deprived of them.

And that because of this fact, these growths do not occur in pipes, where the supply is a ground or a filtered water free from microscopic forms.

TABLE I.

TEMPERATURE OF THE WATER IN THE DISTRIBUTION PIPES, BOSTON, MASS.
(Fahrenheit Degrees.)

MONTH.	1891.		1892.		1893.		1894.		1895.		Av. 1891-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	39.9	42.0	38.1	43.4	36.7	38.5	41.3	39.6	37.6	40.3	38.7	40.8
February	40.7	39.9	38.8	40.3	36.1	35.9	37.0	38.1	36.9	38.9	37.9	38.6
March	41.8	39.9	36.8	38.9	35.8	36.0	41.9	38.9	38.0	36.6	38.9	38.1
April	48.8	44.2	46.8	43.6	41.7	39.6	46.4	43.1	43.2	40.1	45.4	42.1
May	56.2	50.7	55.1	49.1	53.7	47.9	59.3	51.1	57.5	49.9	56.4	49.7
June	64.4	56.9	69.0	57.2	65.7	57.2	66.3	57.7	66.7	59.1	66.4	57.6
July	70.8	60.6	73.1	62.9	71.7	62.7	73.6	63.9	69.2	63.2	71.7	62.7
August	72.1	62.9	72.9	64.5	71.1	64.5	72.4	66.3	70.4	63.7	71.8	64.4
September	69.0	62.5	66.7	62.3	65.5	62.4	69.3	63.0	69.3	64.3	68.0	62.9
October	59.9	59.1	57.3	57.4	57.5	57.3	58.0	59.2	57.8	56.6	58.1	57.9
November	47.3	51.4	47.1	50.8	47.0	50.2	46.4	50.6	48.4	51.1	47.2	50.8
December	41.7	47.0	37.9	43.7	42.1	42.8	38.7	42.8	39.6	43.9	40.0	44.0
Mean	54.4	51.4	53.3	51.2	52.0	49.6	54.2	51.2	52.9	50.6	53.4	50.8

TABLE II.

NUMBER OF MICROSCOPICAL ORGANISMS (IN STANDARD UNITS* PER C. C.) IN THE WATER IN THE DISTRIBUTION PIPES. BOSTON, MASS.

Month.	1891.		1892.		1893.		1894.		1895.		Av. 1891-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	75	28	242	109	66	57	60	25	79	78	104	59
February	29	18	139	112	14	9	50	27	14	6	49	34
March	34	13	101	57	5	7	38	13	12	5	38	19
April	188	65	190	191	46	46	152	92	38	26	123	84
May	313	167	267	97	212	103	126	76	93	42	202	97
June	206	80	350	76	308	66	137	72	233	111	247	81
July	356	106	478	212	336	96	125	48	373	155	334	123
August	201	81	212	81	199	49	71	29	188	47	174	57
September	452	124	214	75	347	205	155	85	142	19	262	102
October	374	152	220	78	679	330	173	83	258	63	341	141
November	421	88	111	64	311	84	84	71	138	42	213	70
December	295	68	95	69	155	18	196	269	140	50	176	101
Mean	245	83	218	102	223	92	114	74	142	54	189	81

*One Standard Unit equals 400 square microns.

TABLE III.

Amount of Amorphous Matter (in Standard Units* per c. c.) in the Water of the Distribution Pipes, Boston, Mass.

Month.	1891.		1892.		1893.		1894.		1895.		Av. 1891-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	32	10	160	226	98	122	182	117	94	80	113	111
February	26	16	66	125	84	44	157	128	92	74	85	77
March	30	27	94	149	88	46	166	70	100	61	96	71
April	134	47	136	140	116	72	169	103	132	82	137	89
May	216	40	241	170	396	88	170	75	363	113	277	97
June	271	73	188	250	324	90	197	154	216	98	239	133
July	289	205	214	162	372	125	224	101	332	154	286	149
August	172	89	87	52	318	123	253	152	248	98	216	103
September	102	85	203	76	299	157	273	130	194	95	214	109
October	211	55	181	63	441	187	235	118	236	103	261	105
November	160	51	141	90	447	225	153	113	143	88	209	113
December	180	96	83	79	185	101	164	194	102	67	143	107
Mean	152	66	149	132	264	115	195	121	188	93	190	105

* One standard unit equals 400 square microns.

TABLE IV.

Number of Bacteria per c. c. in the Water of the Distribution Pipes, Boston, Mass.

Month.	1892.		1893.		1894.		1895.		Av. 1892-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	113	92	257	58	73	54	95	69	135	68
February	86	75	690	178	42	84	25	23	211	90
March	120	55	110	52	32	30	146	64	102	50
April	65	65	54	73	32	72	55	37	52	62
May	67	70	63	155	30	107	59	85	53	104
June	61	133	64	171	157	92	62	106	86	126
July	61	161	97	229	46	80	89	156	73	157
August	61	91	103	76	102	65	56	34	81	67
September	102	58	75	51	109	60	58	37	86	52
October	71	46	68	84	29	42	50	17	55	47
November	63	36	59	53	50	30	50	19	56	35
December	39	29	79	84	27	22	65	23	52	40
Mean	76	76	143	105	61	62	67	56	87	75

TABLE V.

NUMBER OF MICROSCOPICAL ORGANISMS, BACTERIA AND AMORPHOUS MATTER IN MYSTIC RESERVOIR AND A TAP IN CHELSEA, MASS. 1890–1893.

Month.	Microscopical Organisms. (Number per c. c.)		Bacteria. (Number per c. c.)		Amorphous Matter. (Number of Units per c. c.)	
	Mystic Reservoir.	Tap in Chelsea.	Mystic Reservoir.	Tap in Chelsea.	Mystic Reservoir.	Tap in Chelsea.
January	233	190	1,712	1,375	429	145
February	79	46	5,500	6,651	426	78
March	1,367	913	539	399	183	41
April	12,796	5,385	566	214	221	61
May	7,667	6,845	107	152	296	196
June	1,684	967	137	94	401	419
July	659	367	122	400	426	266
August	1,164	715	975	840	175	140
September	1,251	483	370	341	203	216
October	543	155	301	218	278	71
November	392	272	118	412	357	84
December	481	235	1,829	894	408	105
Mean	2,360	1,381	1,023	999	317	152

DISCUSSION.

PROF. PORTER: I would like to ask if anything is known as to the effect of the speed of the current on the formation of these growths on the inside of pipe?

MR. WHIPPLE. We know only that where the current is very rapid we do not find them. Where there is no current at all we do not always find them, because food is not being carried to them. The most favorable condition is a gently flowing current, but we cannot give any figures such as the number of feet per second.

MR. FULLER. I would like to ask Mr. Whipple how much flushing is required to remove these growths, whether it is possible by ordinary flushing to remove them?

MR. WHIPPLE. I do not believe that the ordinary flushing would remove them. You have got to increase the current to such an extent that they are really broken from the sides of the pipe. They are very firmly attached, and they are extremely tough.

MR. CHACE. I think the Association is greatly indebted to Mr. Whipple, and to the Boston Water Works, not only for this paper,

but, in general, for their biological studies. I myself feel personally indebted for information I have obtained from the reports of the Boston Water Works. For example, I remember reading in a report a year or two ago that in the Boston water they found the organism Dynobrion very common in spring months, at the time the ice was breaking up, and that the prevalence of this organism produced a bad taste in the water. I immediately looked at the analysis of the waters of our Lakeville ponds to see if we had any there, and I found that it was quite numerous in the Assawompsett water, but not in the Elder's water, so I immediately discontinued drawing from one pond to the other in the month of March. That is one case in which I have received benefit from the work of Mr. Whipple and his associates, and I do not doubt others of you could tell similar experiences.

A Member. I would like to ask Mr. Whipple if there is any coating which can be used to prevent those growths?

Mr. Whipple. That is something I cannot answer, but I propose some time to make experiments along that very line. We know a rough surface favors the growths of organisms, for it furnishes a good place for them to become attached; further than that I cannot say.

The President. I would like to ask Mr. Whipple, if in his examinations he has had opportunity to see whether the difference is perceptible between the number of organisms present in surface water and ground water.

Mr. Whipple. I know, as I said, that in the town of Brookline and in the city of Newton, there are practically no organisms growing in the pipes; that is, I learn so from the superintendents. I have examined the pipes of half a dozen or more surface water supplies in various cities, and I have almost always found them; in fact, I think I have never failed to find them.

The President. I don't know but the Newton and Brookline superintendents may have had examinations made as to whether there were really any organisms in the water pipes, but are you fully posted as to that?

Mr. Whipple. I once asked the superintendent of the Brookline Works particularly regarding that fact, and that is what he told me; and perhaps Mr. Whitney, if he is here, can answer for the Newton water.

THE PRESIDENT. There is no one better aware than Mr. Whipple that to an ordinary observer, the water pipe might look entirely free from any organism whatever, while a biological examination would reveal the fact it was teeming with these organisms. Now, as long as we do not know that there was any microscopical examination of that ground water, I should feel assured that it was full of organisms, certainly to quite an extent.

MR. WHIPPLE. The organisms of which I have been speaking are not microscopical. They are quite easily seen by the naked eye. The large growths are fully a quarter of an inch long, and I don't think anybody would be likely to overlook them; that is, if he were looking for them.

WOONSOCKET WATER WORKS RESERVOIR AND DAM NO. 3.

BY BYRON I. COOK, SUPERINTENDENT, WOONSOCKET, R. I.

[*Read Sept.* 9, 1897.]

Reservoir No. 3, of the Woonsocket Water Works, is situated in the towns of North Smithfield and Smithfield, five miles from the city of Woonsocket, and two and one-half miles from the pumping station on the Crook Fall brook, the same that supplies Reservoirs Nos. 1 and 2. The pumping station is located at Reservoir No. 1, No. 2 being about 1,000 feet up stream from No. 1. The storage capacity of Reservoirs Nos. 1 and 2 is 52,000,000 gallons, with a water-shed of 7.9 square miles. This was insufficient in a dry season, with an average daily consumption of 1,000,000 gallons, and the year previous to the completion of Reservoir No. 3 the city came very near suffering a water famine. Although warned by the Water Board of the necessity of additional storage, it was not until unwatered streets became unbearable from dust, drinking fountains dry, lawn hose useless, and the public out of sorts, that an appropriation was made for the necessary surveys, and purchase of land. (I will say right here, if any Superintendent is ever so unfortunate as to be obliged to ask the water consumers to economize in the use of water on account of short supply or accident, that I hardly think that his request will be complied with to any extent; the only curtailment will be the consumption directly under his supervision, such as drinking fountains, etc. Unless the water consumers of other cities and towns are different than those of Woonsocket, the only one to turn to for aid will be the weather man, and I hope he will help you out as he did in our case.)

Surveys for the proposed reservoir and dam were commenced early in 1894, and during the spring negotiations were commenced for the necessary real estate. Of course land values had advanced in the vicinity of the proposed site. Abandoned farming land was valued as much as corner lots in a flourishing town. It became necessary

to ask the Legislature for an "Act of Condemnation." This was granted at its May session, 1894. All parties interested were settled with, out of court, except two.

The law of Rhode Island grants the right to parties owning land taken under an act of condemnation to have their damages assessed by a jury, and it is surprising the difference of opinion of the men that comprise the jury, of the value of real estate. In one suit for a tract of 50 acres, I was told by one of the jurymen after the trial, that upon retiring to the jury room after the testimony had been submitted, and before the case had been discussed, each man gave his opinion as to the amount of the award. The highest was $8,000, lowest, $900; verdict, $2,800.

The reservoir flows an area of 197 acres. Its greatest depth is 16 feet; average depth, 9 feet; storage capacity, 529,000,000 gallons. Its elevation is 323 feet above tide water, and 167 feet above Reservoir No. 1. It has a water-shed of 1,944 acres of abandoned farming and wood land. Only two farms are under cultivation. The total population of the water-shed in 1895 was 14. Sufficient land was purchased to control the shores of the reservoir, the adjoining ownership at the nearest point being 100 feet from the flowage line, and on the north side, where the shed is the steepest, the land was purchased 1,000 to 1,500 feet from the flowage line.

The reservoir site was cleared of all brush and trees and thoroughly burned over. An estimate was made of the probable cost of removing the soil, and the expense was more than the city could afford. Another consideration entered into the outlay. The water is carried from Reservoir No. 3 to No. 2 in the open brook between the two. The brook has two large tributaries. These drain large swamp areas. It would have been necessary to have drained these swamps if the full value was to have been received from the expense of the removal of the soil in the reservoir. With the progress that has been made in the past few years with filtration of drinking waters, it was considered advisable to investigate the subject before making any large outlay in draining the swamp land.

The dam is located at the easterly side of the reservoir, and was built by contract. It is at present 1,300 feet long, 36 feet wide at top, and 28 feet high at its greatest height. The dam is so designed that when additional storage is required it can be raised 6 feet, increasing the area flowed to 240 acres, with a holding capacity of

875,000,000 gallons, the estimated yield of the water-shed. The dam is built of earth, with a core wall of concrete and 2-inch spruce sheeting. A spillway or overflow, 25 feet in width and 5 feet high, is located in the dam near the southerly end, and is built of granite. The up stream embankment is sloped 2 to 1, and rip-rapped with cobbles not less than 6 inches in diameter. The down stream embankment is sloped $1\frac{1}{2}$ to 1, and is dressed with loam. Two effluent pipes, 20 inches in diameter, placed 3 feet on centers, pass through the dam near the spillway and are encased in concrete. These pipes are 16 feet below the flowage line, and draw the water only at that height. Four 20-inch Chapman valves are placed on the effluent pipes at the down stream end, and are placed 30 inches apart. These valves are flanged and bolted to the effluent pipes. The upper two are always open, the lower set controlling the flow of water. This set, in case of repairs, can be unbolted and passed out under the gate house through an archway, this archway at present being filled with a 12-inch wall.

The material underlying the core wall is of hard pan. Soundings 15 feet below the bottom of the core wall did not reach the ledge. The average depth of the core wall below the original surface of the ground is 15 feet. If it had required it, a single row of hard pine sheeting, 6x12 inches, would have been driven under the center of the core wall.

The core wall is 7 feet wide at the bottom and 3 feet wide at the top. It is composed of one part Rosendale cement, two parts coarse sharp sand, and four parts broken stone, screened to pass a $2\frac{1}{2}$ inch mesh. It was laid in layers of 8 inches and rammed. It extends from the south end of the dam 550 feet, where it is joined to the 2-inch spruce sheeting. The up stream side is plastered with cement.

The 2-inch spruce sheeting, tongued and grooved, 20 feet long, extends from the core wall the remaining portion of the dam. It is footed into 12 inches of concrete. The excavation for the sheeting was refilled with selected material and puddled.

The embankments are composed of blue marl and gravel. The material for the up stream embankment being selected, all material was laid in layers of 4 inches and immersed with water. The constant passing and re-passing of the carts was sufficient to compact the material without the use of a roller.

The spillway was of granite and classed as broken ashler. The steps were of granite, fine pointed on face and top. The coping was fine pointed on face, and peen hammered on top. The steps and coping were laid in Portland cement.

The spillway between the core wall and the up stream shoulder of the embankment was paved with selected stone, not less than 1 foot in thickness.

The spillway apron was laid with large flat stones, weighing not less than 2,000 pounds, laid on concrete and thoroughly grouted, extending 80 feet from spillway steps. In front of effluent pipes an apron of hard pine 6x8 inches, 20 feet long, joined the spillway apron. This apron was laid on concrete.

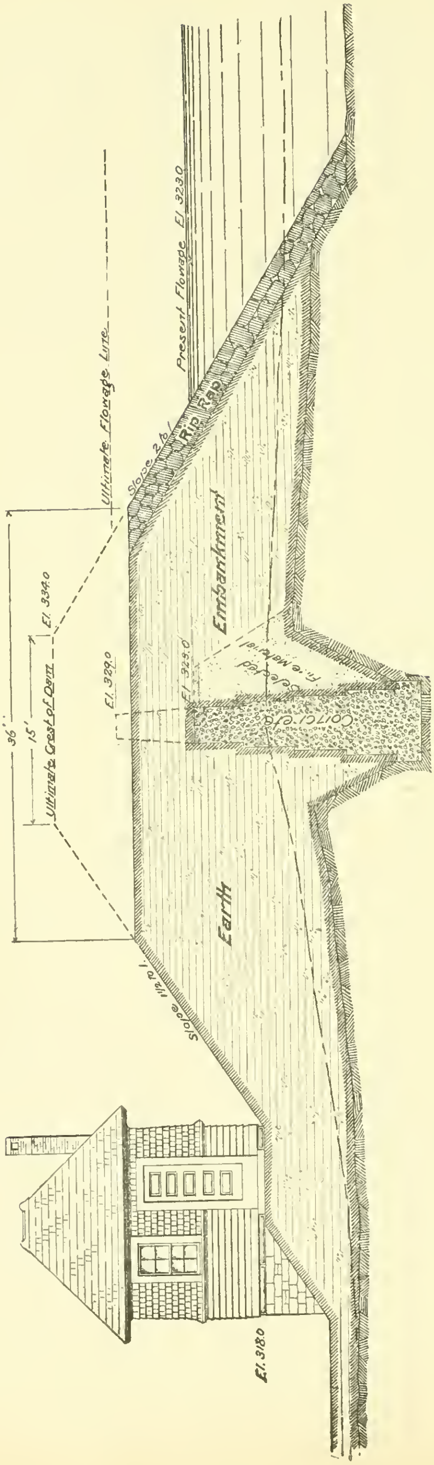
The gate house is of wood, 12x15 feet. A portion of the outside walls are shingled, the inside being finished with hard pine sheathing. All exposed parts of the foundation are of broken ashler. The gate house contains the necessary appliances for the operation of the gates, which were furnished by the Chapman Valve Company.

The Rosendale cement used was the Hoffman brand, and it required 4,474 barrels to complete the work. 1,348 samples were tested for tensile strength. 704 samples, 1 hour in air, 23 hours in water; minimum allowed, 50 pounds; average, 93 pounds; maximum, 177.5 pounds. 644 samples, 1 day in air, 6 days in water; minimum allowed, 70 pounds; average, 114.5 pounds; maximum, 197 pounds.

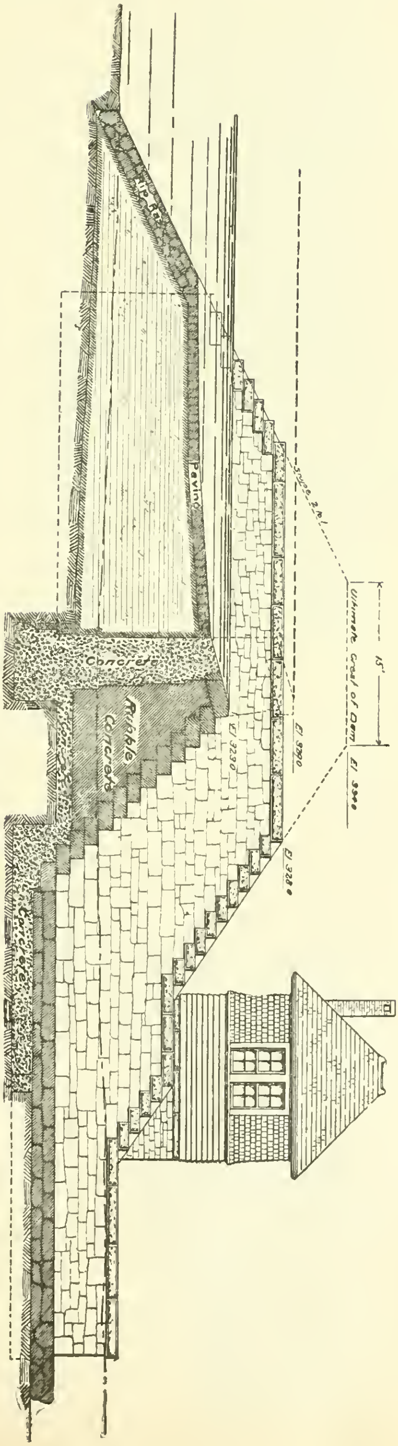
The Portland cement used was the Alsen brand. Number of barrels used, 40. Four samples were tested 1 hour in air, 23 hours in water; minimum allowed, 140 pounds; average, 210 pounds; maximum, 250 pounds. One day in air, 6 days in water; minimum allowed, 235 pounds; average, 305 pounds; maximum, 350 pounds. The cement was delivered at the dam site,—Rosendale $1.25 per barrel, Portland $3.20 per barrel.

The following is the cost of the different quantities taken from force account, and material used:

Grubbing and clearing dam site	$ 0.35	per cubic yard.
Wet excavation, including pumping	.82	" " "
Puddled earth embankment, (avg. haul 800 ft.)	.35	" " "
Rip-rapping up stream slope	.36	" " "
Loaming down stream slope	.31	" " "
Spillway paving	.36	" " "
Concrete, including cement	3.41	" " "
MASONRY.		
Broken Ashler, without cement	$ 25.59	per cubic yard.
Rubble, " "	4.64	" " "
Apron paving, " "	3.60	" " "
Gate house	582.36	



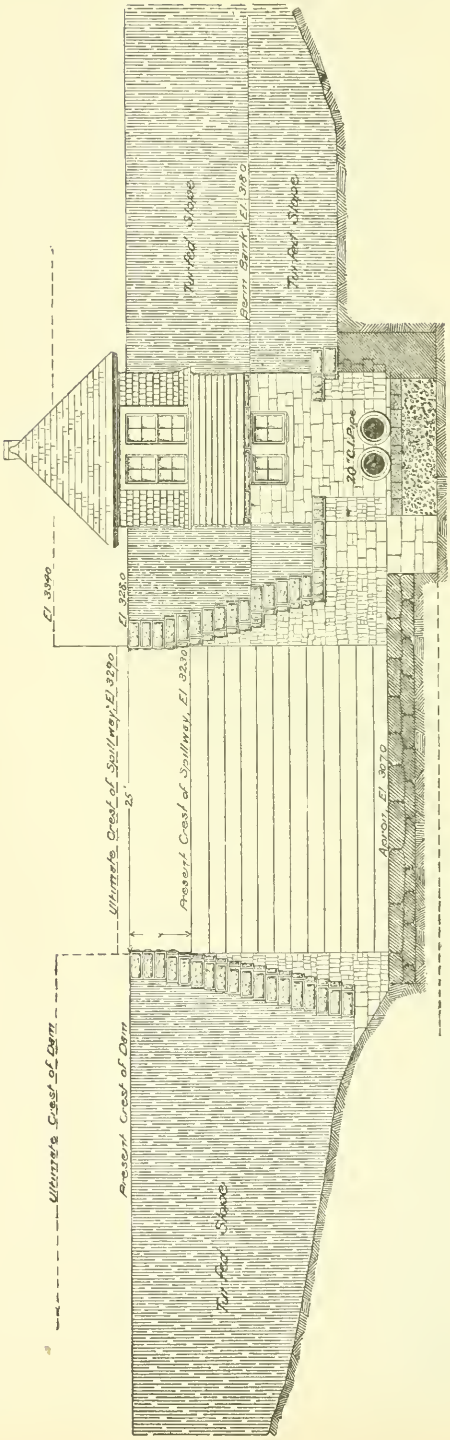
CROSS SECTION OF DAM.
-FACING SOUTH-
SCALE
0 1 2 3 4 5 6 7 8 9 10 FT.
F. A. Caldwell, Del.



CROSS SECTION OF SPILLWAY.

SCALE

F. A. Caldwell Del.



ELEVATION
SPILLWAY & GATE HOUSE.

SCALE

F. A. Caldwell Del.

DISCUSSION.

Mr. Stacey. I would like to ask if the water has been used by the city continuously since the reservoir was filled, in connection with the other water, and if so what has been the result of flowing the reservoir without the removal of any of the soil, and only removing the shrubbery and burning it over?

Mr. Cook. I will say, in reply to Mr. Stacey, that last season it was necessary to draw upon the reservoir. The water starts from the reservoir and runs two and a half miles in the brook, dropping about 167 feet. There has been no complaint, and it has been impossible to detect any trouble with the water at the pumping station. There is no question but it would have been better to have stripped the reservoir of the soil, but the expense was more than the city could stand; and, as I state in my paper, with the subject of filtration in the state in which it is at present, it was decided to wait and, if possible, to filter the water, in preference to draining the swamps and taking the soil from the reservoir.

The President. I would like to ask Mr. Cook if it would have added very much to the expense of this reservoir to have put the spill-way at either side, rather than in the portion of the main dam, where it is?

Mr. Cook. Yes sir, I think it would. And the character of the land each side was not so good for locating the spill-way. I can see Mr. Haskell's point. There is some question about locating a spill-way out in the dam, but where, as in this case, it is thoroughly incorporated in with the core wall.—You will observe on this section that the concrete wall and the backing for the spill-way steps are thoroughly bonded together.—I cannot see how there would be any trouble from leakage at that point. We have never discovered, since the reservoir was built, any leakage at all through the steps, or on them.

The President. I would also like to ask Mr. Cook if he observed during the summer any particular growths of organisms in the water, or has the State Board of Health made monthly analyses of the water and discovered anything?

Mr. Cook. Down here in Rhode Island we are not so particular about such things, or not so well fortified against them, as you are in Massachusetts. Our State Board of Health, so far as regards

water supplies, does very little. But I can say that I did discover in the reservoir, during the first season, a growth. We could not detect anything of the kind at the pumping station, however, and I account for that, as I have said before, by the fact of the water running so far and dropping, as it does, 167 feet, which gives it a chance to aerate itself. At one place within a thousand feet, the brook drops about 60 feet.

Mr. Stacey. If I understood Mr. Cook correctly, he stated that there were tributaries to the brook, draining a large area of swamp on two sides.

Mr. Cook. Yes, sir.

Mr. Stacey. And that has always been so; that is, they were tributary to the original supply.

Mr. Cook. Yes.

Mr. Stacey. And you never had any trouble from the water from this locality?

Mr. Cook. None whatever.

Mr. Stacey. The reason I am interested in this, is that we are in almost the same condition, although we stripped to a certain extent the shallow flowage of our reservoir, and we have 10 feet or more of water on everything that is not stripped. The city of Boston has been building reservoirs lately all around us, and the reservoirs have been put into use as soon as constructed, for the demand for water has kept up with the supply, and there has been a great deal of criticism on the part of some people, because in constructing our reservoir we did not thoroughly clean the bottom. But we have had the same idea Mr. Cook has, in regard to filtration. We looked at it in this way: That it was going to cost us a large amount of money to clean the basin of the reservoir, and we had to spend some money cleaning the shores, and while we might have a clean reservoir, one free from vegetable matter, which would be a very desirable thing, still we would have no defense against the water-shed, which was liable to contamination. By the time we were obliged to draw from that reservoir six or eight months in a year,—we are only obliged now to draw two or three, or possibly four months,—the development in filtration, both mechanical and the European system of sand filtration by irrigation, would have reached such a point it would warrant us in waiting. And it was a question in my mind, whether it was not a better plan to wait until we could adopt some

system of filtering the water as it goes to the consumer, rather than to spend about the same amount of money in cleaning up the comparatively small area of the basin which contains the water, which flows from an unprotected water-shed. We have used that water for three or four years, using it at the time of year when the water is at its best, in the winter and early spring months, and while our original supply was considered excellent, and is so shown by the analyses of the State Board of Health, we have failed to see where there was any difference between the water from the new reservoir and that from the old, at the season of the year when that water is used. Of course there is a great difference between the water at the surface and at the bottom. We took it three or four feet from the top, and we couldn't see any difference either in the color or in the organisms contained in the water.

THE PRESIDENT. I would like to ask Mr. Cook if the character of the bed of this reservoir was sandy, or whether there were muddy areas which had quite a considerable amount of soil and muck?

MR. COOK. The greater portion of the reservoir flowed was of a swampy character. It would have been necessary to have gone to a considerable depth in stripping the soil off the reservoir to have taken all the vegetable matter. The muck in some places was 3 to 4 feet deep, for 50 to 75 feet each side of the channel of the brook where it passed through the swamp.

THE PRESIDENT. I would like to say a few words myself in connection with this matter of cleaning reservoirs. Where a city is putting in a large reservoir, it is a question of great importance. One thing is settled, that we must have purer water than we have been furnishing in the past. The best way to get it is a question which is to-day receiving a large amount of careful study, and there is quite a good deal of difference of opinion among Water Works men as to how to arrive at that result. Boston has perhaps made the greatest effort to purify the basins, where they were starting in for a new water supply, that has been made in the country, and the result has not yet demonstrated that the expenditure of money in that direction can be considered to be the best expenditure which is possible. It is a well known fact, as appears from the reports that the State Board of Health have given of the quality of the water in these cleared reservoirs, that it does not come up to the standard we ought to apply when we talk about giving pure water. There

are times in the year when there are organisms existing in these reservoirs to a greater amount than is desirable, and certainly to such an extent that I should expect to hear from some of our water takers, if we were supplying them with the water.

Now, there is this which can be said in favor of cleaning a reservoir. We all will readily admit that soil and muck, and every substance of that character in a reservoir, favors the growth of organisms, and forms an element from which a great deal of trouble is to be apprehended. But we also know that in former years there was no attempt made to purify water in this way, and we do know that from year to year the basins have improved, so that, varying according to the character of the reservoir, usually within a period of ten years, ponds have been brought to a condition by natural causes that has pretty fairly paralleled what we find in these new cleared reservoirs.

Furthermore, let us consider what is the practical condition of a pond, we will say in ten years after it has been cleared and filled? All these reservoirs have a large amount of water flowing into them in streams, which carry a good deal of soil and other things, depending very much on the character of the water-sheds through which the streams pass. Now allowing that we start with a perfectly clean pond, as is supposed now to be the very best. From year to year all of this floating debris and soil and everything that comes down, is going to be deposited upon the bed of that pond, and it seems to me that experience is going to show us that the natural causes have intervened to render the bed of a pond that has been cleaned almost in the condition in which it formerly was. Now, we haven't had an opportunity to thoroughly demonstrate that, but indications, as I look at them, point to our arriving at that result. Well, if that result is to be reached, it does seem as though this great expenditure of money that we are forced to go to to clean out the bed of a reservoir, is perhaps unwise. As Mr. Cook says, we undoubtedly are going to have filtration as the practical method of purification of surface water supplies, and it looks to me that, granting the water may be somewhat worse in a basin that has not been cleaned, the final result after filtration and purification is going to be practically the same. And it does seem, as both Mr. Cook and Mr. Stacey have said, that it is a question which requires quite a little deliberation before we spend too much money in cleaning out reservoirs.

Mr. Cook. Mr. Haskell's remarks have been just in the line of the arguments which were used in our case. As I have said, the trouble with the Woonsocket water is the color. If we had gone to the expense of cleaning our reservoir, 197 acres, at an expenditure of not less than $100,000, we should not have been any better off, so far as color is concerned, than we are with the reservoir in its present state. Passing as it does down through quite a large area of swamp, our water would have been just as high colored when we received it at our pumping station as when it left the reservoir, and we considered that in view of the progress which is being made in filtration, it would be better to put our money into a filter plant, either mechanical or sand, rather than into cleaning the reservoir.

Mr. Fuller. I would like to ask Mr. Cook if he made any estimate of the expense of filtering the supply?

Mr. Cook. We did not to any great extent. It is my opinion that a mechanical filter, sufficiently large for our use at the present time, can be put in for about $50,000. The cost of sand filtration we didn't go into. I believe the time is coming when most of the water supplies in New England have got to be filtered, for the people are going to demand it.

Mr. Chace. I suppose the members are aware that ordinary filtration does not remove color. In order to remove the brown color from swamp water, the process of filtration would have to be supplemented by the use of some kind of a precipitant like alum, and the State Board of Health have condemned that, as an excessive amount of alum is likely to be injurious.

The President. I think when we come to the question of color in water we are opening up quite a question. The qualities that give color to water are very distinct, and sometimes color in water does not mean it is bad water at all. There may be a certain amount of carbon in the earth that would color a water very highly, but would not injure the quality of it at all. The principal cause of color in this reservoir is probably the swamps in the water-shed. It might be possible that a very small swamp might have added very much to the color. I have seen water taken from a brook just below a cedar swamp where the color ran up as high as 700. Well, you can readily see how that is going to affect the color in the pond, where the color ought to be probably about .040. Now, if in this water-shed there was an area of 30 acres, and a cedar swamp the

water from which was colored up to 700 at certain times of the year, the remaining portion of that entire area might be down to a very fine color, and still the water in the reservoir be highly colored. Our State Board of Health in Massachusetts think that there should not be any color in the water. Of course that is very desirable, but it is going to be very difficult to get all the color out, and when you get down to .070 it is not perceptible at all in a tumbler. I myself feel that it is sufficiently fine to draw the color line to a point where, when a person picks up a tumbler of water, the water looks colorless. Well, at .070 there are very few who would notice the color, particularly if they were quite thirsty.

I think that there would be no difficulty in bringing the water in the Woonsocket reservoir down certainly to an average of .070, for I have done some careful work in areas that are something like that there, and I have found no difficulty, where we had a color of 300, in reducing it down to .040 by a system of drains running around the portions of the water-shed that the color came from, eliminating all that portion of the water-shed which was above those low figures and stopping the water from running down into the swamp and getting the color. I don't imagine that it would be an item of very large expense to remove the color of the Woonsocket water down to .070. That is something which is going to attract a little attention in the future, the care we take of our water-sheds, for, although filtration may take everything out, it is very desirable not to get anything in. We want to start with the water just as pure as we can get it, and we want to do it in the cheapest way. The different methods have got to be carefully studied, and we are going to know more on this subject than we do now. One way to learn is to talk these things over, and get at the different ideas of the members about them.

Mr. Hazen. The question of color, of course, is an important question;—important, as our President has said, because of the color itself, and not because of any unhealthful property in the color. The coloring matter is something, perhaps, like that which gives color to coffee, and we certainly don't care to have our coffee as light colored as even the darkest of the waters. But it is pleasanter to have a colorless water on the table than a yellow water. It is a matter of taste. We like to have some of our drinks colored, but we like to have our water white.

The question of the removal of color by filtration is a difficult one. Passing water through sand in the ordinary course of filtration always removes some of the color. If the filtration is rapid and the sand layer is not very thick, the proportion of color removed is very small—hardly noticeable. In filtration through a thicker layer of sand and at a lower rate—as, for instance, in the Lawrence filter,—from one-half to one-third of the color of peaty waters is removed, seldom more. The proportion of color removed depends upon the character of the sand. A pure quartz, like the Berkshire sand, removes hardly any color, while some sands, containing a good deal of iron, aluminum or manganese, remove a very large proportion of the color. They may remove all of it for a short time and a large proportion of it for a long time. I had the pleasure last fall of visiting some filters in England for the supply of the city of Liverpool, where the sand had been in use for some thirty years. They were filtering a quite yellow water, and the proportion of color removed at the end of thirty years, without changing the sand, was from two-thirds to three-quarters of the total color of the water, so that the effluent from a very highly colored supply was practically colorless. This sand was very dark colored, almost black, and had an extraordinary property of getting rid of the color. The city of Liverpool has recently constructed some other filters, in which another kind of sand was used which it was thought would be better than that old sand, but it was found that it removed not more than a third of the color.

The color of peaty water can be removed by the use of alum. It takes more alum to remove the color than has been commonly supposed. I have been furnished with records of the amounts of alum actually used in removing colors from peaty waters during the last year, by members of this Association and by others, and I have been surprised at the large amount of alum which it is necessary practically to use to get rid of the color. In the waters of the middle states there is usually a considerable amount of lime carried in solution, which makes the waters hard, and this lime will decompose a large quantity of alum completely, so that almost any quantity that is required in water purification can be added to the water, and the decomposition will be complete, and the alum will be removed, and the sulphuric acid will be in the effluent as sulphate of lime. In many eastern waters, in New England waters particularly, there is

very little lime in solution, and with these waters it is not possible to add large quantities of alum without using up all the lime and leaving an excess of acid and a quantity of undecomposed alum which is objectionable. I have known cases of this kind where quite serious trouble has been caused by rendering the water acid.

A number of other means of removing color have been suggested as a substitute for alum. One of the earliest and most important of these was the Anderson process, in which the water was brought in contact with metallic iron, the idea being to oxidize the iron, forming ferric hydrate, which would do the same work in the water that the alum would do, but without the addition of the sulphuric acid to the water. This process has been in some cases apparently quite successful, but with New England waters it has been found that the iron will not be acted upon fast enough to make it a practical success. It is necessary to keep the water in contact with the iron in motion for so long a time as to make the cost practically out of the question. Recently there have been several schemes suggested for hastening this action by means of electric currents, and aluminum has been suggested to take the place of iron. These processes have been tried in an experimental way in a few cases, but I do not know that any practical results have been obtained from them as yet.

I can simply say that by the use of sand, particularly when a sand can be secure which has a peculiar power for removing color, it is possible to remove a great deal of the color, and in many cases enough can be removed so it will not be objectionable. When the water is very highly colored or filtering material of the peculiar quality is not obtainable, the only way in which to get rid of the color is to use some coagulant or its equivalent, and the best way of getting at that is one of the questions which is still under active discussion and investigation.

Mr. Fuller. I would like to ask Mr. Hazen if the matter that causes the peaty taste in water is the same which causes the color?

Mr. Hazen. So far as I know it is, Mr. Fuller. We certainly find the two things associated with each other and going together.

The President. I should like to ask Mr. Hazen if he has any information to furnish in relation to the relative expense of filtering a city's water supply by mechanical and sand filtration?

Mr. Hazen. The cost of mechanical, and also of sand filtration, depends altogether upon local conditions. In certain cases beds of

sand are found, which are exactly suited for sand filtration, right on the ground. If the places are far enough south so that open filters can be used, sand filters can be constructed very cheaply. In other cases there may not be a sand bank in a hundred miles, and covered filters may be necessary, and the cost will run up to several times the cost of mechanical filtration. The cost of mechanical filtration will also vary very much with what you require. The mechanical filters were formerly operated at the rate of 3 gallons per square foot of area per minute. Now they are running filters at a half or a third of that rate which means a very much larger area. Then it depends upon what is required in the way of a mechanical filter. Some mechanical filters are simply washed by a reverse current; others have stirring devices and other arrangements. If you are satisfied with the simplest apparatus, you can build a mechanical filter very cheaply indeed. But, on the other hand, if the best devices for stirring the sand and regulating the rate of flow, and so forth, are required, the cost of mechanical filters runs up considerably A three million gallon sand filtration plant, which I was interested in last year, and which was built by day labor for about 10 per cent. less than the lowest bid for a mechanical plant of the same capacity. The conditions there were very favorable. Under other conditions the comparison would not be at all the same.

SERVICE BOXES.

BY GEORGE A. STACEY, SUPERINTENDENT, MARLBORO, MASS.

[*Read Sept.* 9, 1897.]

The question of service boxes was brought up at one of our previous meetings, and it was suggested at that time, there being no discussion of the subject then owing to the lateness of the hour, that perhaps there might be some information of a practical nature which, if there was time at this meeting, might be brought out here by bringing up the subject again. It seems almost trivial to speak of a thing like that, but at the same time it is one of the many little things which goes to make up the great whole, and in regard to this, as to many other things, we are not all situated under the same conditions, and do not all think alike. This subject was brought to my mind in the first place by the occurrence several times of trouble in the winter on a cold night,—all our troubles come in a cold night, you know. Of course you go to the place and suppose everything is all right, so you can turn off the water and can get back to bed again, but you find some boy has smashed the box some time during the summer, or a stone has worked in somewhere, and the water can't be shut off. Now the trouble with gate boxes with me is from the displacement or the heaving of the box by frost, the ground being largely composed of hard-pan and clay, which expands to a very large extent in the winter and lifts the box. The gate box we have used has been in two sections, like the majority of the gate boxes, and the last kind which was used was the old Buffalo screw box. When they first came out the thread on the screw was fitted comparatively close. Shortly after that it was made larger in the thread on the upper section, and as small as possible on the lower section, so as to give the box as much leeway to come and go as possible. Well, if they had about six times as much as they have now it wouldn't be any too much. The trouble is the box comes up, and we have to drive it down again,—we have to drive the whole box down. If the bottom comes up, when you drive it

down you will find that the tendency of the material is to work under the box, and if there is a stone anywhere in the vicinity I believe it comes to that place to get up in there. And while you can take some water and get out the soft material by churning it up and down, the stone will not go out, but will stay in there and get in its work. Then we find in boxes where the wrenches go clear down to the stop and waste, that the tops are broken, that they are not heavy enough to stand the work of the small boy, or a coal wagon, or the other things we have to contend with, and the whole thing is disarranged in time by frost, and the boys, and the general hard usage which such a thing gets.

Now in concrete sidewalks, and in places where there is perfect drainage of the land, these troubles would not exist, and in some places in our city where we have concrete walks, and we have a large number of them, we don't have any trouble in this way. But in other sections of the city we will find a box standing up from the concrete walk in the spring of the year sometimes three inches. Of course in the main streets this does not occur, for the boxes are forced down by the travel over them.

My idea of a gate box is that it should be made of two parts, a telescope pattern, the top and bottom entirely separated, as far as any mechanical connection is concerned. The bottom should be of sufficient size to withstand an upward thrust, and fit close enough around the stop and waste and pipe to exclude the possibility of any material getting around it. The top should be perfectly free, with a very generous flange, and with a cover sunk into it so it will stand any ordinary hard usage. When you can get a box of that kind and set it, you will be pretty sure to find it in the same condition in which you set it two or three years afterwards. The rod should extend enough so you can get a wrench onto it, and it must be heavy enough so that corrosion will not weaken it, so that it will not twist off and leave you in worse shape. You must have it sufficiently heavy to compensate for the corrosion which will take place, and which, as a general thing, takes place right in the stop-cock. If the two parts of the box are not separated, so the top section can come and go freely without disturbing the base, then a stone or other material is likely to get in so that even with your rod up where you can get at it, you are not sure of shutting the stop-cock off. It looks to me as though we might devise a box that

will exclude the material from the bottom, which will give the top a chance to rise and fall, and which can be driven down by a man going along the street, without disturbing the bottom of the box.

I have seen one or two boxes which have been brought here by some of the members, one of which comes very close to my idea of what a box should be, except that for use in our soil the top section, which is telescoped onto the lower section, would have to be longer than it is, for it must extend below the frost line in a severe winter. We have a winter once in eight or ten years which is colder than other winters, when we find the frost three and a half to four feet deep. Of course in filled ground it will go down six feet, but that is not a fair ordinary condition. We often go through frost three and a half feet on the south side of a street, and on the north side in our town (I don't know how it is elsewhere) there is certainly from six inches to a foot difference between the depth of the frost there and on the south side of the street. One objection I would have to the box to which I refer is that it simply stands on top of the pipe, and there is no protection against anything working up into the box, and there is no foot on it to give it stability. It should have a flange much larger than that has, so it would have as much holding power as the large base does on the regular gate box. My idea of the stop would be to have the same thing that we have on our mains, a first class gate, with a rod of some substance which would not corrode, and which would give you a chance to put a wrench on it and turn it as easily as you can a faucet. I would like to hear from some of the other members, as to whether they have had any trouble with their service boxes. If I have had it all I won't say anything more about it, but will try to bear it.

Mr. Gilbert. I would like to ask Mr. Stacey if he believes it is the best plan to have a rod attached to the shut-off in the sidewalk? I understood him to say that his were arranged in that way.

Mr. Stacey. No, sir, I haven't got a rod. I put in two, but I came to the conclusion I wouldn't put in any more. If I put in a rod again I don't think it will be less than seven-eighths of an inch in diameter. (Laughter.)

Mr. Gilbert. I would say I never put in but one, and I broke that the first time I tried to use it. Of course we all have trouble enough with the service boxes, and I never have found one yet which I thought was just the right thing. I know the common

Buffalo box in some respects is very good, but the tops, I think, are not made right. If they come up to the top of the ground, as we sometimes use snow plows in our town they are pretty sure to scrape the top off, or if something else heavy runs over them they are pretty sure to be broken, and the small boy, of course, takes delight in taking off the top and filling up the box with stones. It seems to me that some of these manufacturers of water works goods ought to put a little thought upon this subject. Perhaps they may think it is a small thing, but it would save us lots of trouble if they would get us up the right kind of a box. I think, in the first place, they are made too light, so they break too easily. If a wagon runs onto them. with any kind of a load, it is pretty sure to break them, to crush them, and there are many places around the town where that is happening, and we have lots of trouble by their breaking. I have noticed a box in some cities; I never could seem to find out where it was made, or exactly how it was made, only as I could judge from seeing it in the sidewalk; I have noticed it has a large nut in the center, and the top is set in in some way. It seems to me to be a better box than I have ever used, and I would like to inquire if anyone here has ever used a box of that description, and can give me some information about it.

Mr. Fish. I have had some experience with boxes, and have tried a good many of them. The conditions in which we use them are perhaps the worst existing in any place you can find in the country. I have found nothing so serviceable as a good heavy 4-inch pipe, a heavy soil pipe, cut off to the proper length and fitted over the pipe, with a cap extending down four or five inches, so it will not be jarred off or worked off, but will lift off freely by getting hold of it. I have had some experience with rods attached to the cocks, and I never put one on unless we had what we call a reverse-cock; that is a plug going in from the bottom, so any pressure coming on top of the rod would loosen it. Then a light rod will be serviceable and work well. This plug is kept in place by the water under the bottom. It is large, fully an inch on the bottom, which gives a water pressure which keeps it up in place, and it will never wedge or get tight, so you can easily loosen it and turn it. As I say, we have got right down to using plain pipe almost entirely.

Mr. Gilbert. I have been told by some of the manufacturers of such goods that a box such as I describe would be too expensive.

Now a matter of fifty cents on a sidewalk box is nothing, if they will only give us a better box than these common cheap boxes. The cheapest articles are not always the cheapest in one sense of the word, and I would be willing to pay a proper price for a good service box if I could find one.

Mr. Fuller. If we had room at our headquarters, I think it would be a good thing to have a collection of all sorts of service boxes, with a statement of where they are used, and what they cost, and how they are made, and so forth. And, in connection with that, I think it would be a good thing to have samples of different kinds of service pipes, properly labelled as to the length of time they had been in, the conditions of the soil in which they had been placed, and so on. Last night we had a very interesting talk in regard to the different kinds of service pipes, and if the members would contribute samples that they had taken out, and they could be labelled properly, it seems to me it would make a very interesting collection.

[Mr. Stacey brought into the hall a service box belonging to Mr. Holden, which he explained to the convention as meeting his views in some respects, while criticising it in others.]

Mr. Chace. I would not have a center rod on any account. If I shut off a man's water because he doesn't pay his bill, I should expect with that thing there he would find some way to take the cap off and turn the water on himself.

SERVICE PIPES DEFECTS AND THE REMEDY.

BY GEORGE F. CHACE, SUPT., TAUNTON, MASS.

[*Read Sept.* 8, 1897.]

It may be doubted whether the ideal service pipe has yet been found. No material or combination of materials has thus far proved an unqualified success.

The discussions of this topic at previous meetings of the Association have disclosed the fact that the majority of Superintendents prefer lead for service pipes. Their second choice is cement-lined wrought iron pipe, with a goose neck lead connection between the iron and the corporation cock, for convenience in the fitting and adaptation to the practical difficulties of exact grade.

The obvious objection to lead is the haunting shadow of possible lead poisoning. Experience has, of course, shown that many waters do not act injuriously upon lead, a protective coating being soon formed. Other waters do dissolve the lead, and for such, lead service is unsafe. There is, to the cement-lined iron, an objection which leads me to state some of our Taunton difficulties, hoping to draw out from the experience of others a discussion which may lead to some practical good result.

Small iron pipes not only rust out soon and leak, but often become filled with rust and sediment, to an extent which lessens the flow of water, sometimes so much as to make a service practically useless. Lining the pipes with cement has not, in my experience, wholly removed the evil. However much pains may be taken with the lining, the cement at the connections and at such bends as may occur in the pipe becomes more or less broken, the water comes in contact with the iron, and there is also, between the bronze of the service cocks and the iron of the pipe, a galvanic action, which tends to fill the service cocks with rust and thus stop the passage of water. Formerly the couplings were lined as follows: two nickel plated brass thimbles, like the samples, were put together at their flanges, the inside forming a cylindrical ring for the flow of the

water, and the space between the outside of the thimbles and the inside of the couplings was filled with solder as far as the thread on each end of the coupling.

I have brought for exhibition a sample of a coupling thus prepared for use, and another sample of one taken out from a place where there had been complaint of poor service.

Having found, as will be seen by the rusty sample, such linings of the couplings to be apparently failures, we have abandoned the practice of lining couplings, and use them plain.

I have prepared a record of our work on poor services, for the years beginning with 1892 and ending with 1896. At the end of our financial year, Nov. 30, 1892, we had in use in Taunton, 3,507 services. We had, during the year, 109 cases of poor supply, about 3.1 per cent of the whole number of services.

The majority of these cases were remedied by disconnecting at the stop-and-waste in the cellar, and running a large wire through the service pipe as far as the service cock, and often as far as the corporation cock. When this method failed to make the service clear, the work of the wire was followed by the use of a small pipe of $\frac{1}{4}$ inch internal diameter. If, on account of the excessively bad condition of the service pipe, or because of too many bends, the above method was fruitless, then the last resort was to dig up the service and clean out the pipe, or in one or two cases, to replace with a new pipe. Of the 109 cases of poor service in 1892, there were 20 where the corporations had to be cleared out, and 8 cases where the whole service was dug up, making in all 28 instances of digging up a part or the whole of a service.

39	of these services	had been	set	15 years or more.
75	"	"	"	10 " "
8	"	"	"	only 5 years.
1	"	"	"	less than one year.

Three times, during 1891 and 1892, services were stopped by large eels; twice they plugged up the corporation, and one filled the whole eighteen inches of the lead connection.

They were all alive when found, about three-quarters of an inch in diameter, and from a foot to a foot and one-half long.

The meshes of the screens in use would not allow the passage of a small lead pencil, and the eels could not have passed the valves of the Gaskill pumps. They must have got in when small and

grown in the pipes. It is not surprising that small pipes should fill up in the course of ten or fifteen years, but it would not seem to me that they ought to fill up in five years.

I felt much disturbed during the winter of 1892 to find that we were having so much complaint of poor service. I thought then that one cause of the filling was to be found in the fact that Taunton city water was imperfectly filtered—mixed river and ground water, which contained considerable iron. This gave rise to a growth of crenothrix, which, when in mass, not only has the appearance and effect of iron rust, but is somewhat gummy, and thus readily clogs up the pipes.

We were then in the midst of our work on the Lakeville extension for a new water supply. I therefore hoped that when we should have in use the new supply from the Lakeville ponds we should have less trouble with the services. My hopes were the stronger because the services which we had to clean contained not simply rust but a great deal of sticky muck.

In order to show what the actual facts have been I will give the records of 1893, 1894, 1895 and 1896 in regard to poor services in tabulated form.

Financial year ending November 30, 1893:

Number of corporations dug up	8
Number of whole services dug up	20
Number of services cleaned out with wire	48
Number of services replaced by new service pipe	1
Total number poor services	77

Financial year ending November 30, 1894:

Number of corporations dug up	1
Number of whole services dug up	10
Number of services cleaned out with wire	83
Total number poor services	94

On April 5, 1894, the Lakeville water was first supplied to the city. For about two months we still continued to use the old filter basin during the night pumping, but since that time nothing but Lakeville water has been used, except for about one day a year, when we clean the gate-house at Elder's.

Financial year ending November 30, 1895:

Number of corporations dug up	1
Number of whole services dug up	1
Number of services cleaned out with wire	30
Total number of poor services	32

Financial year ending November 30, 1896:

Number of corporations dug up	0
Number of whole services dug up	0
Number of services cleaned out with wire	26
Total number of poor services	26

The whole number of services in use November 30, 1896, was 3,955, so that the number of poor services was less than .7 of one per cent, against 3.1 per cent in 1892. Moreover, of these 26 cases of poor service—

11	had been set	15	years or more.		
3	"	"	20	"	"
21	"	"	10	"	"
1	"	"	4	"	"

This last was on a street where the main had been changed during the year from a 6-inch to a 12-inch pipe, and the service had been supplied during the change through an unlined 2-inch pipe, laid temporarily along the curb. I feel justified from these facts in the belief that the character of the water supply has much to do with the condition of service pipes.

There may even be some disadvantage in using a very pure water. The total average amount of solid matter in the water of Elder's Pond, Lakeville, in 1895 was 2.88 parts per 100,000, while in the filter basin during the same year it was 4.89, and in the river 5.24.

In Taunton, the house cold water pipes are mostly unlined wrought iron. I have known these pipes, since we have used Lakeville water, to be badly rusted in two years. I infer that the less pure water of the past formed a coating on the inside of the iron pipes, thus preventing further corrosion, while the present pure water keeps rusting the exposed surface, especially where there is a constant change of temperature from pipes, through a part of

their course, passing near the furnace in the cellar or near hot water pipes.

I have come to believe that the best service pipe at present in the market is tin-lined iron pipe. It costs more than cement-lined iron, or than lead-lined iron.

But for all-round use, for waters good and bad, soft or hard, it is free from the peril of lead, and it may be hoped that experience will show it to be more trustworthy than cement-lined iron. Time and experience may reduce the cost of the tin-lined iron. I have begun to use it and expect success.

The defects of service pipes are known to all. The remedy seems to be: get the best water supply possible, watch the market for every improvement in service pipes, study your own supply and defects of service, and, by experiment and consultation with brother Superintendents, learn the way to progress and to ultimate perfection.

DISCUSSION.

Mr. Hawley. We have been having in Atlantic City very much the same experience as the gentleman who has just read his paper has had. I have here a piece of half-inch pipe, which was galvanized once; it is solid now with the accumulations of rust in the past ten years. When the works were first constructed, in 1882, they began to use lead pipe. This was expensive and the people objected to the cost, and the company finally began using galvanized pipe, and its use has been continued until within the past year. During the past year we have renewed 150 galvanized services. It is impossible to clean this pipe after the rust accumulates. We have a total of about 3,700 services, and out of that number we have renewed, as I have said, 150 the past year from curb to main. We have been looking about for something to take the place of galvanized pipe, and I have finally come to exactly the same conclusion which the gentleman who has just read the paper has reached, that tin-lined iron pipe is the best thing on the market for the money. We cannot use lead, because our water is partly swamp water, a considerable amount of vegetable matter in it, which seems to attack the lead, and the Board of Health won't allow us to use it. We are using tin-lined pipe galvanized on the

outside. The lining has proved satisfactory, whereas the coating on the outside of the pipe has not.

Mr. Fish. I would like to ask the gentleman if there are electric cars in his city?

Mr. Hawley. In Atlantic City we have an electric railroad crossing all of our cross-mains, and running parallel to the pipes of the two different systems on Atlantic avenue. We have had absolutely no trouble from electrolysis. The electric road is controlled by the Pennsylvania Railroad Company, and the rails are thoroughly bonded and there is a return conduit to the power station, and this may account for our having no trouble. The only case of electrolysis we have had was on the service which supplied the railroad company's car barn, and at that point the rails, I believe, are not bonded as they are elsewhere. As to the effect of brass and iron, or lead and brass connections in our street connections, we have had no trouble at all.

Mr. Chace. We have electric cars in our city, and I had some fear of electrolysis. Fortunately we had an opportunity two years ago to see whether anything was happening or not, because along two streets where the electric cars run we took up old mains and replaced them with larger ones, and I took pains to look to see if I could find any evidence of any injury to the services or the mains. I am happy to say nothing of the kind was found. The cars had not been running very long, not more than two or three years.

Mr. Fish. I have had some experience in this direction. I have been putting in galvanized iron services for thirty years. I have pipes which have been in now for thirty years, and they are still in pretty good condition. I have others that haven't been in three years, which have badly filled up and rusted and have holes in them. In some cases mains have been corroded to that extent that they have burst, and we have had to take them up, and in such cases I have noticed the services have been badly affected. This condition I have attributed to electrolysis. You won't find much trouble in dry ground, but in moist ground electrolysis has a bad effect on the services and the mains. The service pipes will feel it first.

Mr. Cook. I would like to inquire how far this was from the power house.

Mr. Fish. In one case it was about 1,500 feet. I have had cases in pipe entirely off the line, on a side street, at least 1,000

feet from the street car tracks. The worst trouble I have noticed is where an iron pipe is conected with brass; in fact, that makes a galvanic action of its own.

Mr. Bancroft. I would like to ask Mr. Chace if he has found more defective services on low ground or on high ground, or if he has found them equally distributed?

Mr. Chace. I think there has been more trouble in wet ground, but some were noted on high ground.

Mr. Gilbert. I think this is a question we are all very much interested in, and it is rather a hard one to solve. Now, in my experience (and, of course, all of us have had more or less trouble from the filling up of pipes) it has not always been the pipe which filled up first. The fittings, the corporation cock at the main, and also the shut-off in the sidewalk, I have found to be the first to fill up. I think if we would all use a corporation which is finished on the inside and made perfectly smooth, and also a smooth shut-off at the sidewalk, we should do away with a great deal of this trouble. I know that pipe will fill up, as a general thing, in from about 10 to 15 years, but I think if we could avoid trouble in the connections they might last perhaps considerably longer.

More than half of our services are metered where the pipe comes through from the ground into the cellar, and I find considerable trouble with the connections, in the shut-off or between the shut-off and the meter. When a complaint comes to me that a service pipe is not doing its duty, I always look there first. I disconnect the meter, and very often I find the shut-off all filled up. And I might say in four cases out of five there wouldn't be a hole through as large as the small end of a pipe stem. Of course the service wouldn't be very satisfactory with the fittings filled up like that. After clearing this out, if we don't get the proper pressure, then we run a wire through, as has been stated here by the gentleman in his paper, as far as the shut-off at the sidewalk and clear it there; and if that does not produce the right effect we dig it up at the main, and there in most every case I find the same difficulty that I found back of the meter in the cellar, that the connection has filled up.

We have used cement-lined service pipe, and that, as we all know, will not fill up as quickly as an iron pipe. We never have used galvanized pipes at all. We have laid some lead, but, as the gentleman from Atlantic City has said, so our Board of Health would

not allow us to lay it. We did lay a litttle of the lead-lined pipe, but they would not allow us to lay that, and so we have continued with the cement-lined pipe. Now I am very careful about the corporation, and I have the sidewalk cock made with a full finished hole also. Many people, where they have their piping in the cellar done outside of the water works department, use these cheap shut-offs which have an oblong hole through them and unfinished, and there is no part of the service pipes which will fill up so quickly. In my opinion we should be very careful to use nothing for a shut-off or corporation that hasn't a finished surface on the inside.

Mr. Richards. Some 12 or 15 years ago I investigated this matter of service pipe carefully, and embodied the result of the investigation in a paper which I read before the Association. The conclusion I arrived at then was that lead was the best and the cheapest service pipe, except in exceptional waters; and I have seen no reason yet to alter that determination. As regards tin-lined iron pipe, the pipe which was made at that day under a patented process was made by expanding a tube of tin inside the iron pipe. I don't know how it is made at present.* But the result of the use of that was that water penetrated around the end of the tin tube, rust formed between the tin and the iron, compressed the tin tube in the pipe, and filled it up. The conclusion I arrived at then was that tin-lined iron would not do. We have used lead continuously with very satisfactory results.

Mr. Bancroft. I remember but three cases where service pipes on our works have been clogged up. The first one was a long iron cement-lined pipe—I think the service was about 150 feet in length. This became clogged and was cleaned out with a wire, as has been described, but it closed up again. The pipe was then taken out and was found to be nearly filled, while the sidewalk cock and the corporation were entirely free. A lead-lined service pipe was laid in the place of this cement-lined pipe, and after a period of possibly a year, complaints came in again that there was no flow of water through the service. That was dug up and was found in about the same condition that the cement-lined pipe was in. Those were both three-quarter inch pipes—that is, the cement pipe was one inch lined

---

*The manufacturer of tin-lined pipe desires the editors to say that the pipe as at present manufactured is superior to that referred to.—*Editors.*

with cement, making a three-quarter pipe. I took out the lead-lined pipe and put in an inch and a quarter galvanized pipe, thinking I would have a pipe large enough so as to allow room for some filling up. That pipe has been in service now about two years, and we have had no complaints from it. It is on about the lowest ground we have, I think, in fact, it is the lowest service we have.

Another pipe, which was of lead, a long service, as I remember it, was about 200 feet, has been closed up and cleaned twice, I think, by the use of the wire, and it is still in service.

Mr. Fish. Two years ago, I think it was, some member of this Association made a statement of an experience of his, where he had put in three service pipes about the same time, side by side, one of which filled up and gave a great deal of trouble, while the other two remained perfectly clear. These pipes were neighbors, within about 200 feet of each other, and were all galvanized pipes. I think it was the gentleman from Burlington who made the statement, and he raised the question whether there was not something in the quality of the iron itself which might account for the results. It seemed a very strange thing to me at that time, and it did not agree with my experience. I would like to know if any gentleman here has thought anything more of the subject since then, or has ascertained whether one kind of iron has a different capacity for filling up than another. The gentleman from Burlington stated his experience very clearly, but there was not much discussion of the matter at that time, because we were about adjourning for dinner, which seemed to be more important just then than closed up pipes.

Mr. Gilbert. A year ago last winter I had a service which commenced to leak, and I had it dug up near the house, and found it leaked there. We put in a new shut-off, and still it kept leaking, and we finally dug up the whole service from the house to the street. The pipe had been laid about five years, and I found it was full of holes from one end to the other. It was laid in low ground, where it was wet nearly the year round, but it was not on any street where electricity could have had anything to do with it at all. I could account for its condition in no other way than by laying it to the kind of iron of which the pipe was made.

Mr. Fish. I think the gentleman may have been mistaken in his conclusion that electricity could not have had anything to do with it. It is not necessary that a pipe shall be near a line of street

cars in order to be affected by the electric current. If the cars run on the line of a main pipe anywhere, it may take an offset and follow the main pipe around. I have known cases where that has happened. I do not think there is much trouble to be feared from electrical corrosion if the connections between the rails are kept good, but there may be an off-set of 1,000 feet, or 2,000 feet with a poorly laid road.

Mr. Richards. I will say that sometimes, if a service pipe is laid in a street which has been filled in with coal ashes, the ashes will "beat electricity out of sight" in eating up the pipe. That happens once in awhile.

Mr. Naylor. About four years ago I laid some tarred pipe in a wet place, and about two months ago I had a burst in it and took it up. I found the pipe entirely eaten away. In some places for a couple of feet it seemed to be all eaten from the outside. In another locality I ran across a piece of pipe of this same kind, which was laid 18 years before, and it was just as fresh as if it was newly laid. This was upon a hill, where everything was dry. So it seems to me that a good deal depends upon the ground that the pipes are laid in. It is our experience in Maynard that our pipes rust from the outside quicker than from the inside. We do not seem to have any trouble with the inside of cement-lined pipe, but we have a good deal of trouble with the outside.

Mr. Porter. It seems to me it would be interesting to know if anyone else has had experience with defects in the use of tin-lined iron pipe, because, even if this is not the ideal pipe, it seems to promise very well for use in special cases. I know I put it into my own house, in a case where, perhaps, it was unnecessary, as a precaution, as we had had a very unfavorable experience in the family with the use of lead pipe, and we desired to avoid every possibility of danger that we could. If there are weaknesses in the use of this pipe, such as have been spoken of, I think it would be very desirable to have them made known.

The President. If anyone can answer Mr. Porter's question from experience, we would like to hear from him now. Our experience with tin-lined pipe is rather limited. Personally I know nothing about it, for I haven't used any of it, and it is comparatively new. Apparently there is no one here who has had experience with it long enough to state anything about it.

Mr. Bancroft. We have been using lead-lined pipe for three years. We haven't used any tin-lined on services, although I have put some of it into my own house. We have never had any trouble with the lead-lined pipe, such as has been spoken of as occurring with the tin-lined. I don't know why it should not apply to one as well as to the other, and I suppose the process of lining with tin is the same as the process of lining with lead at the present time.

Mr. Richards. I will say the pipe I referred to was made, my impression is, some 10 or 15 years ago, by New York parties, who made a specialty of tin-lined iron pipe at that time. Whether it was made in the same manner that tin-lined iron pipe is made at present I do not know, but that was made by expanding a tube of tin inside of the iron pipe. The result of using it was as I have stated, and in quite a number of cases it had to be taken up.

Mr. Beals. Why should not the same experience be had with tin-lined iron pipe as with block tin, regardless of the iron? I have had some experience, not in connection with our water works system, but with one or two wells in town, before we had our system of water supply, where the parties thought they would get the best thing they could and selected block tin. In two years the pipe was so honeycombed they could not pump water through it; they pumped air. I wonder if they would not be liable, with the same water, to get the same result in the use of tin-lined iron pipe—that is, that the tin would honeycomb and the water would go through it and rust the iron.

It seems to me there must be some difference in plain iron pipes. I have in mind now a service—our regular service pipes are cement-lined iron—I have in mind a house which was piped, after the service was in the cellar, with plain black iron pipe, and I have had complaints enough from that this year to make a superintendent run mad almost, of the quality of the water in that service. The woman of the house said it was so poor she could not use it; she had tied a cloth over the faucet and had tried to filter it in all ways, but she had to go to her neighbor's to get water she could use. Now, the neighbor's house was piped with the same class of pipe, plain iron. Well, the owner of the building finally took out the old piping entirely and put in new iron pipe, and the lady of the house comes around and says the water is tip-top. Now, it seems to me

there must be some difference in iron pipe, because there are two houses within 200 feet, both piped with plain iron, and in one case the water was so bad that the people had to go to the other house to get their water, and when the old pipe was taken out and new put in there was no further trouble.

Mr. Hawley. When this matter of a change in the material for services came up last spring, in conversation with some of the plumbers I was told by one of them that he had used some tin-lined pipe 10 or 12 years ago, and at my request he took out several pieces of the pipe and showed it to me. I don't know the process by which that was manufactured, I don't know who manufactured it, or where it came from, but the tin was in perfect condition, while the iron was somewhat corroded from the outside where it had been in the ground. I based my recommendation of tin-lined pipe on that. Now, as to the difference in iron pipes. There is unquestionably a difference in quality. I know of services today in Atlantic City that have been in 10 or 12 years which are still very satisfactory; and I know of other services of the same size, which have been in less than half the time, which have completely filled, or practically so. I have seen a $\frac{3}{4}$-inch galvanized pipe which has been in four years and a half so filled up it had less than the capacity of a $\frac{1}{4}$-inch pipe, and I have seen other services of the same kind, which have been in longer than that, where the pipe is still comparatively free.

Mr. Bancroft. As the question of electrolysis has been brought up here, I would like to inquire if anybody can tell how small a voltage on a pipe line will do damage to pipe, either to a main or services?

The President. I would answer the gentleman's question by saying that a little was bad and a good deal was worse. We have heard considerable about lead-lined pipe being injurious to health, or I take it that that is what has been meant. Now, Mr. Richards has lived in a city, and has had charge of the water works there, and in his long experience there has been no trouble from the use of lead-lined pipe. There are other gentlemen here who have felt serious ill effects from its use right in their own families. This would seem to show conclusively that lead-lined pipe may be affected by some waters and not affected by others. I used to feel a good deal of fear about the use of lead-lined service pipe, but I have been

getting over that fear lately, from the fact that the authenticated cases of poisoning from its use have received so little prominence. If there is anybody here who has a well authenticated case of poisoning from water through a lead-lined pipe, I should like to hear a little something in that direction.

MR. NAYLOR. When a gentleman of our town built his house he had a driven well and put in a very heavy lead pipe. The members of his family have been sick more or less ever since, and there have been a number of deaths. At one time, after our water works were put in (his house was a considerable distance from our main pipe), he ordered his machinist to come up and see what was the trouble with his pump. They kept fixing the pump and fixing it, and finally they came to the conclusion the trouble was not above but below, for whatever they did they couldn't make the pump work. So they got down into the well, and when they got there so as to get hold of the pipe, it crushed right up. The water had eaten the lead pipe entirely away so there was nothing left but a shell which was all full of holes. He was satisfied that the water had eaten the lead and they had drunk it. So he sent for me and wanted to know how soon I could get our water into his house, for he didn't want to drink another drop out of the well. We put the water in, and I believe they have had better health as a family since they stopped using well water through that lead pipe.

THE SECRETARY. What sort of a pipe are they drawing their water through now?

MR. NAYLOR. They are drawing the water through a 4-inch iron pipe, cement-lined, into the cellar, and tarred iron pipe up to the sink.

MR. RICHARDS. I agree with you, Mr. President, that I should like to know of a well authenticated case of lead poisoning from the use of a lead service pipe. I know of cases of poisoning from a pipe running from a well, from a spring and from a lead-lined tank, and other similar cases, but I never heard of a case in connection with a service pipe running from a water main into a house, and I have never seen a description of such a case anywhere in this country, although I have looked for them continually. And I doubt very much if there ever has been a case of lead poisoning from a service pipe extending from a water main into a house and constantly filled with water, unless the water was of exceptional quality.

We are talking about service pipe now, and not talking about pipe from wells or pipe from springs, which is a different thing entirely.

Mr. Hazen. I would refer the gentleman to the reports of the English local government boards for a good many hundreds of cases. In some of the English cities, notably Sheffield, where the water is a surface water from reservoirs, distributed through iron mains and lead service pipes, the water occasionally becomes acid and takes up the lead from the service pipes in quite large quantities; and there have been, not single cases, but hundreds and thousands of cases of lead poisoning at those times. The remedy which has finally been adopted is to treat the water in a certain way to remove the acid and make it alkaline, and when that is done the trouble from the solution of the lead disappears.

A Member. This question has been brought up in a manner which would tend to make us ask for more correct information than we have had on this subject. We have used in our works lead pipes for over 50 years, and have had no trouble whatever from any defect on the inside of the pipe. They have been eaten on the outside, where they have been laid in coal ashes, or certain kinds of clay. I think it would be a matter of useful information to the members of this Association if gentlemen who have used lead pipes on their works would communicate their experience to the Secretary, for if there are any injurious results from the use of lead pipe, we ought to know it and in an authentic manner.

Mr. Bancroft. In my remarks before I stated we were using lead-lined pipe for service pipe, and that I had used a tin-lined pipe in my own house. I did not use tin-lined pipe from any fear of the lead-lined pipe, but for the purpose of experimenting with the tin-lined.

Mr. Porter. I have used tin-lined pipe somewhat for the same reason that the gentleman has just stated, but partly also as a precaution. The unfortunate experience to which I alluded a while ago was this—that a member of our family died a few years ago from illness which was declared by an able physician to be unquestionably the result of lead poisoning, and several other members of the family appeared to have been affected by it also. This was shown by analyses by Prof. Wood, of the Harvard Medical School. Now, the source of that poisoning was never known with certainty, but it was supposed in the case of the person who died to have been

in water from a spring in the country, which was carried through about 700 feet of small lead pipe to the house; but it was running continuously, never stopped. In the case of city service pipes I suppose, from all I have heard and read, that there is ordinarily very little danger, but I suppose there may possibly be some danger from the use of the water by a servant in the morning from pipes in which it has been standing all night long. Practically that is a very slight danger, but I think it is one perhaps worth considering.

PROCEEDINGS OF THE SIXTEENTH ANNUAL CONVENTION.

NEWPORT, R. I., September 8, 9, 10, 1897.

The headquarters of the Association during the convention were at the Ocean House, and the sessions of the convention were held in the large parlor of the hotel.

WEDNESDAY, SEPTEMBER 8, 1897.

The convention was called to order at 11.50 a. m. by President Haskell.

On motion of Mr. Holden the reading of the minutes of the last meeting was dispensed with.

The President introduced His Honor Patrick J. Boyle, Mayor of Newport, who spoke as follows:

ADDRESS OF WELCOME BY MAYOR BOYLE.

Mr. President and Members of the New England Water Works Association, Ladies and Gentlemen:

It affords me much pleasure to meet you today and bid you welcome to our city. We assure you that we are much gratified to have with us the representatives of that business or profession that has done so much in the past, and will, we hope, do so much more in the future for the common good. I assure you that we are very much pleased to have you here, but the welcome which I extend to you must at the best seem, I am afraid, rather a cool one. We unfortunately (with all due respect to the wisdom of the early founders of this city of ours) live under a charter which prohibits the city government from appropriating money for the purposes of entertaining such bodies as yours. I simply call your attention to this fact in order that you will understand that we do not lack appreciation of your coming, and regret that as a city we are unable to take fitting recognition of your presence.

Coming as you do from different parts of New England, you must be acquainted with the many attractions in Newport, and I there-

fore will not detain you from your business by any reference to them. I hope that your deliberations will result in the improvement of the sanitary condition of your respective communities, and I sincerely trust (and I think I have my fellow citizens with me when I say it) that your deliberations will result in some improvement in our local water matters here.

Ladies and gentlemen, I hope you will have a pleasant time while you are with us, and that when you leave us you will take home with you many pleasant recollections of your visit. (Applause.)

RESPONSE BY PRESIDENT HASKELL.

Mr. Mayor:

In behalf of the New England Water Works Association I desire to thank you for your friendly interest in our welfare, and to extend to you and to the citizens of Newport a cordial invitation to attend our meetings.

It has long been the desire of the members of this Association to visit this beautiful city, situated on the picturesque shores of Narragansett bay, and abounding as it does in so many natural and historical objects of interest, enhanced by the lavish display of art, made possible by the possession of great wealth. Although it has always been the object of these meetings to add to our fund of useful knowledge in all that appertains to the proper conduct of a water supply, it has been our custom in the past to devote a portion of our time to recreation, assembling, as we have done, in different cities from year to year, and visiting the principal objects of interest to be found in the immediate vicinity. While our stay with you will be short, I do not doubt that our members will avail themselves of every opportunity to its utmost.

The convention then proceeded to the regular order of business.

ELECTION OF NEW MEMBERS.

The Secretary presented the following list of applicants for membership, with the approval and recommendation of the Executive Committee:

RESIDENT ACTIVE.

Frank S. Bailey, Assistant in City Engineer's Office, Brockton, Mass.; John D. Adams, Water Commissioner and Superintendent, Provincetown, Mass.; Thomas H. Rogers, Pumping Engineer for the Pennichuck Water Works, Nashua, N. H.

NON-RESIDENT ACTIVE.

Harry A. Lord, Superintendent, City Water Works, Ogdensburg, N. Y.; W. C. Hawley, Superintendent Water Department, Atlantic City, N. J.; Robert S. Weston, First Assistant Chemist, Louisville Experiment Station, Louisville Water Co., Ky.

ASSOCIATE.

Lead Lined Iron Pipe Co., Wakefield, Mass.; W. K. Helmer, Agent Holly Manufacturing Co., Lockport, N. Y.; Kennedy Valve Co., 75 John St., New York.

On motion of Mr. Fuller, the Secretary was empowered and directed to cast the vote of the Association in favor of the applicants, which he did, and they were declared by the President elected to membership.

The President then delivered his annual address.

ADDRESS OF PRESIDENT HASKELL.

Gentlemen of the New England Water Works Association :

We are now assembled to hold the sixteenth annual convention of this society. The usual time for our annual meeting is in June.

The reasons that led to the adoption of this later date were the better facilities afforded for our accommodation here, and that many of our members can better afford to take this time to be absent from their routine of duties.

Since our last meeting, death has removed from our membership:

Albert F. Noyes, Civil Engineer, Boston, Mass.; Richard R. Yates, Superintendent, Northboro, Mass.; Jos. A. Lakewood, Superintendent, Yonkers, N. Y.; Charles B. Brush, Engineer and Superintendent, Hackensack Water Co., Hoboken, N. Y.; Jas. Hugh Stanwood, Prof. Civil Engineering, Institute Technology, Boston, Mass.; Ezra Clark, President and Superintendent, Hartford, Conn.; Wm. E. Nason, Superintendent, Franklin, Mass.; Wilmer Reed.

Among their number the most familiar countenance was that of Mr. Noyes, a former president of this Society, and also an ex-president of the Boston Society of Civil Engineers. His genial presence and hearty interest in our welfare displayed at all of our meetings will be sadly missed.

Our membership is still increasing; we now have 464 Active, 80 Associate, and 5 Honorary members, a total of 549. We must, however, bear in mind that numbers alone do not constitute the greatest strength, but that the best results can only be secured by

earnest work on the part of those who, having valuable knowledge, are willing to contribute it for the benefit of others.

The principal good to be derived from this Association is to be gathered from the papers contributed and the opportunity afforded for the discussion of any points not fully understood.

Our regular meetings have been well attended and a lively interest was shown in the various papers presented.

On September 9th, 1896, the Society visited the Hobbs Brook Reservoir, a new addition to the Cambridge Water Supply, containing 2,000,000,000 gallons storage capacity. Under the guidance of Mr. L. M. Hastings, the City Engineer of Cambridge, an opportunity was given to inspect the method of construction employed in building the lower dam, and the extensive removal of soil and muck from the bed of the reservoir, which was being excavated five feet, whenever that depth of soil was found, necessitating the removal of 1,900,000 cubic yards of material.

On June 9th, 1897, a visit was made to the Metropolitan Water Works at Clinton, where a reservoir is to be built for the Metropolitan district of 63,000,000,000 gallons storage capacity.

Under the guidance of Chief Engineer Stearns and Deputy Engineers Richardson and Miller, the party proceeded over the site of the reservoir through a portion of the tunnel and along the line of conduit to the bridge upon which the conduit crosses the Assabet river.

These excursions to works of such magnitude, presented many instructive features. A severe rainstorm interfered somewhat with the pleasure of each day.

During the most intense heat of the summer our permanent headquarters in the Tremont Temple supplied us with a cool and comfortable place in which the current magazines of the day and a library containing an extensive fund of information on the subject of Water Works could be examined. Our short experience in its occupancy has fully demonstrated its value.

As we look over the problems presented in procuring a water supply for a large city, the question of the purity of the water furnishes a subject of vital interest to all. All will admit that pure water is necessary for the preservation of health. Many instances can be cited in recent years where efforts to improve the quality of water supplied has reduced the death rate of a community in a marked degree.

The remarkable discoveries made by medical science of recent date have shown more fully than was possible in the past, the intimate relation that water bears to perfect health.

These undeniable facts present to us most forcibly the question of water purification. The experience of the past shows us most conclusively that natural ponds cannot be depended upon at all times to furnish pure and wholesome water, and that artificial reservoirs are still more unreliable. The solution of this problem will undoubtedly be reached at a no distant date, through Legislative enactments making the thorough filtration of all surface water supplies compulsory.

It is with feelings of deep regret that I announce the resignation of Mr. Allen Hazen, the senior editor of the JOURNAL, who will not be able in the future to fulfil the duties of that office.

In conclusion I desire to thank all who have assisted me in the effort to make our meetings interesting and instructive.

The Treasurer then submitted his annual report as follows :

REPORT OF THE TREASURER.

George E. Batchelder, in Account With the New England Water Works Association.

RECEIPTS.

1896.	Balance on hand as per last report :		
	People's Savings Bank.	$1,052.64	
	City National Bank	416.74	
	Safe Deposit and Trust Co.	1,235.07	
			$2,704.45
July 21.	Received from J. C. Whitney, Secretary	$ 700.00	
Dec. 30.	" " " "	400.00	
1897.			
Jan. 8.	" " " "	200.00	
" 19.	" " " "	300.00	
" 29.	" " " "	250.00	
Mch. 1.	" " " "	300.00	
May 11.	" " " "	300.00	
June 1.	" " " "	300.00	
" 3.	" " " "	300.00	
" 8.	" " " "	150.00	
			$ 3,200.00
Aug. 1.	People's Savings Bank, interest	$ 63.76	
Sept. 1.	Safe Deposit and Trust Co., interest	69.47	
" 1.	City National Bank, interest	7.00	
			$ 140.23
			$6,044.68

EXPENDITURES.

1896.			
June	12.	James T. Almy, badges ....$	8.96
"	12.	Frank De Silva, lettering door of headquarters ..	1.86
"	12.	Newton Journal, printing circulars and postals..	16.50
"	12.	A. T. Thompson & Co., lantern service, Lynn...	22.70
"	15.	Alfred Mudge & Son, printing postals, etc.......	8.00
"	16.	Irving & Casson, upholstering two chairs	40.00
"	24.	Bacon & Burpee, reporting Lynn meeting.......	75.00
"	30.	Fanning Printing Co., printing envelopes.......	3.00
July	1.	Thos. Campbell, 2d, table for Lynn meeting ...	5.02
"	1.	Electro-Light Engraving Co., electro for adv....	1.08
"	14.	Newton Journal, printing envelopes, circulars and postals	9.00
Aug.	2.	The Oxford Club, Lynn, hall for June meeting ..	55.00
Sept.	1.	J. C. Whitney, stamps, stationery, express, telegrams, telephone, etc	99.31
"	1.	J. C. Whitney, salary to Sept. 1, 1896	125.00
"	4.	Miss A. B. Knowlton, typewriting	14.00
"	18.	The Heliotype Printing Co., plates and half tone plates	51.18
Oct.	1.	Stephen F. Cate Estate, barges for Sept. meeting	22.00
"	10.	The Heliotype Printing Co., two half tone plates.	6.00
"	12.	W. H. Richards, salary to Sept. 1, postage, freight, express, etc	86.03
"	15.	Boston Society of Civil Engineers, rent of rooms to Sept. 1, 1896	150.00
Nov.	2.	Mrs. A. D. Wood, basket of roses...............	10.00
"	24.	Alfred Mudge & Son, printing June Journal......	294.80
Dec.	8.	Electro-Light Engraving Co., five half tones engineering constructions.........................	28.31
"	11.	The Heliotype Printing Co., one zinc plate	1.68
"	12.	J. C. Whitney, express, freight, telegrams, telephone, etc..	15.40
"	12.	J. C. Whitney, salary to Dec. 1, 1896	125.00
1896.			
Dec.	14.	W. H. Richards, salary, telegrams, telephone, express, typewriting, etc.	99.69
"	14.	The Heliotype Printing Co., 850 copies each two diagrams and one map	39.00
"	31.	Alfred Mudge & Son, printing September Journal	183.00
1897.			
Jan.	1.	Boston Society of Civil Engineers, rent of rooms to Jan. 1, 1897..............................	100.00
"	25.	Newton Journal, printing circulars, etc	9.00
Feb.	24.	The Heliotype Printing Co., 870 copies plan of New Bedford Water Works..................	17.50
		Amount carried forward.......................	$1,723.02

		Amount brought forward	$1,723.02	
Feb.	26.	The Heliotype Printing Co., five half tone plates.	27.60	
Mch.	8.	Newton Journal, printing circulars and envelopes	21.50	
"	11.	Bacon & Burpee, report of winter meeting	75.75	
"	15.	The Heliotype Printing Co., one half tone plate	5.52	
"	26.	W. H. Richards, postage, express, telegrams, typewriting and salary to March 1	99.96	
"	27.	J. C. Whitney, back numbers of Journal, express, telegrams, typewriting, etc	116.60	
"	27.	J. C. Whitney, salary to March 1, 1897	125.00	
"	31.	Fanning Printing Co., 850 half tones of A. F. Noyes	5.00	
Apr.	7.	Alfred Mudge & Son, printing December Journal.	191.75	
"	8.	The Heliotype Printing Co., one half tone plate	5.52	
"	10.	The Heliotype Printing Co., one zinc plate map	2.60	
"	14.	The Heliotype Printing Co., one half tone pencil drawing	5.06	
"	21.	The Heliotype Printing Co., three half tone plates	16.56	
May	21.	Allen Hazen, services of assistant, express and telegrams	34.50	
"	24.	Electro-Light Engraving Co., one eng. diagram	1.04	
"	27.	The Heliotype Printing Co., 3,050 copies plans water filter at Ashland, Wis	28.50	
June	1.	Boston Society of Civil Engineers, rent to June 1, 1897	150.00	
"	7.	W. H. Richards, salary to June 1, 1897, postage, express, etc	84.56	
"	7.	J. C. Whitney, postage, express, typewriting, travel, etc	19.97	
"	7.	J. C. Whitney, salary to June 1, 1897	125.00	
July	3.	Alfred Mudge & Son, printing March Journal	384.83	
"	3.	W. H. Richards, postage, express, telegrams, telephone, etc	35.85	
Aug.	28.	Alfred Mudge & Son, 900 copies and 800 slips of three cuts and rebinding 100 pamphlets	8.25	
"	28.	Newton Journal, printing postals, receipts and circulars	7.25	
"	28.	J. C. Whitney, back numbers of Journal	21.75	
				$3,322.94

BALANCE ON HAND.

Aug.	1.	People's Savings Bank	$1,116.40	
Sept.	1.	Safe Deposit & Trust Co	1,377.48	
"	1.	City National Bank	227 86	
				$2,721.74
				$6,044.68

Respectfully submitted,

GEORGE E. BATCHELDER, *Treasurer.*

Examined, audited and found correct.

A. R. HATHAWAY, } *Finance Committee.*
A. W. F. BROWN, }

September 4, 1897.

On motion of Mr. Beals, the report of the Treasurer was accepted and placed on file.

On motion of Mr. Holden, the report of the Auditing Committee was accepted and placed on file.

The Secretary submitted the following as his report:

REPORT OF THE SECRETARY.

Summary of Statistics Relative to Membership for Year Ending June 1, '97.

ACTIVE MEMBERS.

June 1, 1896, total active membership		442	
Withdrawals during the year		11	
		431	
INITIATIONS:			
June, 1896	15		
December, 1896	6		
January, 1897	2		
February, 1897	5		
March, 1897	5		
		33	
June 1, 1897, total active membership			464

HONORARY MEMBERS.

June 1, 1896, total honorary membership		5	
June 1, 1897, total honorary membership		—	5

ASSOCIATE MEMBERS.

June 1, 1896, total associate membership		82	
Withdrawals during the year		6	
		76	
INITIATIONS:			
June, 1896	1		
December, 1896	2		
January, 1897	1		
		4	
June 1, 1897, total associate membership			80
June 1, 1897, total membership			549

A gain for the year of 20.

Summary of Receipts for the Year Ending June 1, 1897.

DR.

Received for advertisements	$ 1,355.00
" initiation	166.00
" annual dues	1,508.00
" Journals	149.00
" miscellaneous	22.00
	$3,200.00

Cr.

1896.		
July 20.	Paid Geo. E. Batchelder, Treasurer .... $	700.00
Dec. 30.	" "	400.00
1897.		
Jan. 8.	" "	200.00
Jan. 18.	" "	250.00
Jan. 27.	" "	300.00
Mch. 8.	" "	300.00
May 10.	" "	300.00
May 29.	" "	300.00
June 2.	" "	300.00
June 7.	" "	150.00
		$3,200.00

On motion of Mr. Beals, it was voted that the report be accepted and placed on file.

AFTERNOON SESSION.

Edward V. French of Boston opened the afternoon session by reading a paper entitled "Loss of Pressure Caused by Meters on a Factory Fire Supply." The paper was discussed by the President, Mr. Fish, Mr. Walker and Mr. Fuller, and in answer to suggestions by them, Mr. French explained more fully certain matters considered in his paper.

The next paper was by Frank L. Fuller of Boston, and related to "Sinking Funds." The President and Messrs. Smith, Gilbert, Beals and Hawley took part in the discussion which followed.

Henry A. Cook, Supt., Salem, Mass., was announced upon the program to speak upon "The Water Supply of Salem." Mr. Cook announced that he had not had opportunity to prepare a paper, but at the request of certain members of the Association he exhibited two tools which he had found convenient to use in his work. One was a very ingenious electric lighting arrangement, which can be easily carried by the workman, used for examining the interior of a service box. The other was an appliance for removing an obstruction, like a small stone, from a service box.

EVENING SESSION.

At the evening session George C. Whipple, Biologist and Director of the Mt. Prospect Laboratory, Brooklyn Water Department, Brooklyn, N. Y., read a paper entitled "Some Observations on the Growth of Organisms in Water Pipes." Messrs. Fuller, Chace and the President took part in the discussion.

George F. Chace, Supt., Taunton, Mass., read a paper on "Service Pipe Defects and the Remedy." There was a long discussion upon this paper, participated in by Messrs. Fish, Bancroft, Hawley, Gilbert, Richards, Naylor, Porter, Beals and Hazen.

Mr. Hazen presented to the convention Mr. Nicholas Simin, Chief Engineer of the water works of Moscow, Russia, who, he said, had come a very long distance to attend the meeting of the Association, and he trusted the members would give him a cordial welcome. Mr. Simin was received with loud applause. He responded in his native language. [The following translation of what he said was kindly furnished by his daughter, who, with a lady friend from Moscow, is accompanying Mr. Simin upon his tour in this country :]

Ladies and Gentlemen : I am very glad to be among you in your beautiful country. America is a country where people know how to approach each question bravely, and rapidly to come to its solution, conquering all the hindrances met on the way. In America it is not only spoken of things, but it is done, and done quickly, without delay.

The progress of the technique is here astonishing. The water works art, for the study of which I came here, has received in your country an immense development, which answers perfectly well to all the requests put by science and by life.

Gentlemen, I thank you heartily for your amiable attention, and I welcome you as intelligent representatives of the water works art of your great country. (Loud applause.)

THURSDAY, September 9th.

At the morning session Mr. Byron I. Cook, Superintendent, Woonsocket, R. I., read a paper entitled "Reservoir and Dam No. 3, Woonsocket Water Works." The paper was discussed by Messrs. Stacey, Chace and Hazen, and the President.

Mr. George A. Stacey, Superintendent, Marlboro, Mass., spoke on "Service Boxes," and was followed by Messrs. Gilbert, Fish and Fuller.

Mr. Henry F. Jenks of Pawtucket, R. I., who had charge of the exhibit of associate members, presented his report.

Mr. W. C. Hawley, Superintendent, Atlantic City, N. J., then addressed the convention, giving the results obtained by the use of water meters at Atlantic City.

In the evening Mr. Frederick P. Stearns, Chief Engineer of Metropolitan Water Board, gave an illustrated talk on the "Metropolitan Water Supply of Massachusetts."

He was followed by Mr. H. F. J. Porter with a talk on "Steel Forgings," illustrated by stereopticon views of the machinery and interior of the shops of the Bethlehem Works, and the processes of manufacture.

FRIDAY, September 10th, 1897.

The first business was the election of new members. The Secretary read the following names of applicants, duly approved and recommended by the Executive Committee:

RESIDENT ACTIVE.

Arthur F. Estabrook, Water Commissioner, Leicester, Mass.
E. V. French, Civil Engineer, Boston, Mass.
J. B. Putnam, Superintendent, Westboro, Mass.
Franklin H. Robbins, Civil Engineer, Boston, Mass.
J. A. St. Louis, Water Registrar, Marlboro, Mass.
Chas. W. Sherman, Civil Engineer, Boston, Mass.

NON-RESIDENT ACTIVE.

Geo. B. Bassett, Civil Engineer, Buffalo, N. Y.
A. D. Clark, Secretary Water Company, Kane, Penn.
Wm. H. Dean, Analyst, Wilkesbarre Penn.
A. S. Gear, Superintendent, Supply Yards, New York City, N. Y.
Harvey M. Geer, Civil Engineer, Ballston Spa, N. Y.
James H. Harlow, President Pennsylvania Water Company, Wilkinsburg, Penn.
Hibbert Hill, Biologist Laboratory Brooklyn Department of Health, Rockville Centre, Long Island, N. Y.
Emil Kuichling, Chief Engineer, Water Works, Rochester, N. Y.

ASSOCIATE.

Buffalo Meter Company, Water Meters, Buffalo, N. Y.
B. F. Smith & Bros., Driven Wells, Boston, Mass.

On motion of Mr. Fuller, the Secretary cast the ballot of the Association in favor of the applicants, and they were declared elected.

ELECTION OF OFFICERS.

Mr. Coggeshall, for the Nominating Committee, reported the following list of officers for the ensuing year:

PRESIDENT.

WILLARD KENT, Manager Water Company, Narragansett Pier, R. I.

VICE-PRESIDENTS.

MELVILLE A. SINCLAIR, Superintendent, Bangor, Me.; CHARLES K. WALKER, Superintendent, Manchester, N. H.; F. H. CRANDALL, Superintendent, Burlington, Vt.; JOSEPH G. TENNEY, Superintendent, Leominster, Mass.; BYRON I. COOK, Superintendent, Woonsocket, R. I.; THEODORE H. MCKENZIE, Manager, Southington, Conn.

SECRETARY.

JOHN C. WHITNEY, Water Registrar, Newton, Mass.

TREASURER.

GEORGE E. BATCHELDER, Water Registrar, Worcester, Mass.

SENIOR EDITOR.

JOSEPH E. BEALS, Superintendent, Middleboro, Mass.

JUNIOR EDITOR.

WALTER H. RICHARDS, Superintendent, New London, Conn.

EXECUTIVE COMMITTEE.

LOUIS M. BANCROFT, Superintendent, Reading, Mass.
JOHN C. HASKELL, Superintendent, Lynn, Mass.
A. H. SALISBURY, Superintendent, Lawrence, Mass.

FINANCE COMMITTEE.

A. R. HATHAWAY, Water Registrar, Springfield, Mass.
A. W. F. BROWN, Water Registrar, Fitchburg, Mass.
WILLIAM MCNALLY, Marlboro, Mass.

Mr. Holden moved that the report of the committee be accepted, and that the Secretary be directed to cast the ballot of the Association for the nominees.

At the request of Mr. Cavanagh the motion was divided, and the convention voted to accept the report of the committee.

Mr. Cavanagh then moved that the name of Mr. Robert J. Thomas, of Lowell, be added to the nominations for the Executive Committee. Mr. Salisbury thereupon withdrew his name, which had been presented by the nominating committee, and the convention voted to substitute the name of Mr. Thomas. Then, on motion of Mr. Cavanagh, the Secretary was directed to cast the ballot of the Association for the nominees, and they were declared elected.

President Haskell, on leaving the chair, spoke as follows:

Gentlemen of the New England Water Works:

I take pleasure in presenting to you Mr. Willard Kent, whom you have elected to preside over the affairs of this Association for the ensuing year. I trust you will all give to him throughout the year your most hearty support. (Applause.)

President Kent responded as follows:

Gentlemen:

I thank you. I assure you I fully appreciate the honor of the presidency of the New England Water Works Association, and I regret that I have not the command of words fittingly to express that appreciation. With your assistance I will endeavor to maintain the present high standing of the Association, so far as it is within my power.

On motion of Mr. Holden the convention adjourned.

Attendance at Convention held September 8, 9 and 10, 1897.

Active Members.

Abbott, E. L., Boston, Mass.
Bates, Oren B., Clinton, Mass.
Bancroft, Lewis M., Reading, Mass.
Bisbee, F. E., Auburn, Me.
Batchelder, G. E., Worcester, Mass.
Beals, Jos. E., Middleboro, Mass.
Brooks, E. C., Cambridge, Mass.
Baldwin, Chas. H., Boston, Mass.
Bigelow, James F., Marlboro, Mass.
Bowers, George, Lowell, Mass.
Brackett, Dexter, Boston, Mass.
Bartlett, R. S., Norwich, Conn.
Coggeshall, R. C. P. New Bedford, Mass.
Chace, George F., Taunton, Mass.
Cook, Henry A., Salem, Mass.
Chadbourne, E. J., Wakefield, Mass.
Cook, Byron I., Woonsocket, R. I.
Codd, W. F., Nantucket, Mass.
Cavanagh, John F., Quincy, Mass.
Crowell, Geo. E., Brattleboro, Vt.
Crandall, Geo. K., New London, Conn.
Crawford, J. W., Lowell, Mass.
Chandler, C. E., Norwich, Conn.
Doane, A. O., Newton, Mass.
Daboll, L. E., New London, Conn.
Estabrook, A. F., Leicester, Mass.
Fish, J. B., Scranton, Pa.
Fuller, F. L., Boston, Mass.
French, E. V., Boston, Mass.
Gould, Amos A., Leicester, Mass.
Glover, Albert S., Boston, Mass.
Gilbert, J. C., Whitman, Mass.
Gleason, T. C., Ware, Mass.
Gear, A. S., New York, N. Y.
Huntington, Jas. A., Haverhill, Mass.
Hawley, W. C., Atlantic City, N. J.
Haskell, John C., Lynn, Mass.
Holden, H. G., Nashua, N. H.
Hayes, A. G., Middleboro, Mass.
Hastings, V. C., Concord, N. H.
Hazen, Allen, New York, N. Y.
Hyde, H. N., Newton, Mass.
Harrington, G. W., Wakefield, Mass.
Hammatt, E. A. W., Boston, Mass.
Hill, W. R., Syracuse, N. Y.
Kent, Willard, Narragansett Pier, R. I
Kuichling, E., Rochester, N. Y.
Kempton, D. B., New Bedford, Mass.
Kingman, Horace, Brockton, Mass.
Kieran, Patrick, Fall River, Mass.
Luther, Wm. J., Attleboro, Mass.

Locke, James W., Brockton, Mass.
Morse, J. W., Natick, Mass.
McKenzie, T. H., Hartford, Conn.
Northrop, F. L., Milford, Mass.
Nichols, Edw. C., Reading, Mass.
Naylor, Thomas, Maynard, Mass.
Perry, F. G., Pawtucket, R. I.
Pollard, W. D., Pottsville, Pa.
Putnam, J. B., Westboro, Mass.
Porter, Dwight, Boston, Mass.
Rogers, H. W., Haverhill, Mass.
Richards, W. H., New London, Conn.
Robertson, W. W., Fall River, Mass.
Sullivan, J. C., Holyoke, Mass.
Smith, H. O., Leicester, Mass.
Sinclair, M. A., Bangor, Me.
Stacy, George A., Marlboro, Mass.
Salisbury, A. H., Lawrence, Mass.
Snow, Edwin W., Somerville, Mass.
Stearns, F. P., Boston, Mass.
Smith, John E., Andover, Mass.
Taylor, L. A., Boston, Mass.
Thomson, John, New York, N. Y.
Tower, D. N., Cohasset, Mass.
Tenney, J. G., Leominster, Mass.
Thomas, R. J., Lowell, Mass.
Whitney, J. C., Newton, Mass.
Welch, J. Alfred, Methuen, Mass.
Winslow, George E., Waltham, Mass.
Wiswall, E. T., West Newton, Mass.
Wallace, E. L., Franklin Falls, N. H.
Walker, Chas. K., Manchester, N. H.
Whipple, G. C., Brooklyn, N. Y.
Watters, Joseph, Fall River, Mass.
Whittemore, W. F., Leicester, Mass.
Zick, W. G., New York, N. Y.

HONORARY MEMBERS.

"Engineering News," of New York, by M. N. Baker.

"Engineering Record," of New York, by H. C. Meyers, Jr., and C. J. Underwood, Jr.

"Fire and Water," of New York, by F. W. Sheppard.

ASSOCIATE MEMBERS.

Ashton Valve Co., Boston, Mass., by C. W. Houghton.

Artesian Well Co., Providence, R. I., by Ray S. Baker.

Ashcroft Mfg. Co., Boston, Mass., by J. A. Mitsch.

Blossom, Albert A., Salem, Mass.

Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.

Chadwick Lead Works, Boston, Mass, by A. H. Brodrick.

Chapman Valve Co., Indian Orchard, Mass., by E. L. Ross.

Coffin Valve Co., Neponset, Mass., by F. E. Adams.

Crosby Steam Gage and Valve Co., Boston, Mass., by Samuel G. Reed.

Deane Steam Pump Co., Holyoke, Mass., by Wm. Burnham, A. M. Pierce and F. H. Hayes.

Eagle Oil and Supply Co., Boston, Mass., by T. J. Babcock and C. N. Goward.

Hersey Mfg. Co., Boston, Mass., by J. E. Safford and J. A. Tilden.

Jenks, Henry F., Pawtucket, R. I.

Kennedy Valve Mfg. Co., New York, N. Y., by M. J. Gilmore.

Lead Lined Iron Pipe Co., Wakefield, Mass., by Thos. E. Dwyer.

National Meter Co., New York City, by John C. Kelley and J. G. Lufkin.

Neptune Meter Co., New York City, by H. H. Kinsey.

Rensselaer Mfg. Co., Troy, N. Y., by Fred S. Bates.

Ross Valve Co., Troy, N. Y., by William Ross.

Anthony P. Smith, Newark, N. J., by W. H. Van Winkle and A. P. Smith.

Sumner & Goodwin Co., Boston, Mass., by F. D. Sumner.

Benj. C. Smith, New York City, by Fred A. Smith.

Thomson Meter Co., Brooklyn, N. Y., by S. D. Higley, E. T. Ivins and Henry C. Folger.

Union Meter Co., Worcester, Mass., by J. P. K. Otis.

Henry R. Worthington, New York City, by O. P. Boller and J. M. Betton.

Wm. Wolfendale, Fall River, Mass.

R. D. Wood & Co., Philadelphia, Pa., by Jesse Garrett.

George Woodman & Co., Boston, Mass., by F. L. Howland.

GUESTS.

Ames, C. N., Brockton, Mass.
Bancroft, L. M. Mrs., Reading, Mass.
Beals, Jos. E. Mrs., Middleboro, Mass.
Batchelder, George E. Mrs., Worcester, Mass.
Bacon, James P., Cambridge, Mass.
Burke, M. F., Marlboro, Mass.
Burke, F., Marlboro, Mass.
Bowers, George Mrs., Lowell, Mass.
Bacon, J. P. Mrs., Cambridge, Mass.
Clancey, J. C. Mrs., Syracuse, N. Y.
Codd, W. F. Mrs., Nantucket, Mass.
Carpenter, L. Z., Attleboro, Mass.
Crandall, George K. Mrs., New London, Conn.
Coggeshall, R. C. P. Mrs., New Bedford, Mass.
Clifford, T. C. Mrs., Providence, R. I.
Dean, G. A., Attleboro, Mass.
Daboll, L. E. Mrs., New London, Conn.
Dowd, M. J., Lowell, Mass.
Doane, A. O. Mrs., Newton, Mass.
Estabrooks, A. F. Mrs., Leicester, Mass.
Fish, J. B. Mrs., Scranton, Pa.
Fels, August, Lowell, Mass.
Fels, Mrs., Lowell, Mass.
Fels, Miss, Lowell, Mass.
Fels, Miss, Lowell, Mass.
Faborousky, Miss W., Moscow, Russia.
Glover, Albert S. Mrs., Newton, Mass.
Gould, Amos Mrs., Leicester, Mass.
Gilbert, A. W., Troy, N. Y.
Holden, H. G. Mrs., Nashua, N. H.
Hayes, Maria E. Mrs., Middleboro, Mass.
Hayes, F. H. Mrs., Boston Mass.
Hill, W. R. Mrs., Syracuse, N. Y.
Hawley, C. T., Cambridge, N. Y.
Jenks, Henry F. Mrs., Pawtucket, R. I.
Jenks, Dorothy Miss, Pawtucket, R.I.
Kent, C. A. Mrs., Narragansett Pier, R. I.
Kelley, John C. Mrs., Brooklyn, N. Y.
Kelley, S. T. Miss, Brooklyn, N. Y.
Kelley, E. S. Miss, Brooklyn, N. Y.
Kempton, David B. Mrs., New Bedford, Mass.
Lawrence, W. F., Derby, Conn.
Naylor, Thomas Mrs., Maynard, Mass.
Proctor, C. S. Mrs., Lowell, Mass.
Proctor, H. S., Lowell, Mass.
Pollard, W. D., Pottsville, Pa.
Porter, H. F. J., Bethlehem, Pa.
Plunkett, E. J., Marlboro, Mass.
Porter, Dwight Mrs., Boston, Mass.
Rogers, H. W. Mrs., Haverhill, Mass.
Ross, E. L. Mrs., Indian Orchard, Mass.
Spofford, J. E. Mrs., Boston, Mass.
Simin, Nicholas, Moscow, Russia.
Simin, Olga Miss, Moscow, Russia.
Stacy, G. A. Mrs., Marlboro, Mass.
Salisbury, H. Mrs., Lawrence, Mass.
Thomson, John Mrs., New York, N. Y.
Tower, D. Mrs., Cohasset, Mass.
Tilden, C. F., Cohasset, Mass.
Tilden, J. A. Mrs., Boston, Mass.
Van Winkle, W. H. Mrs , Newark, N. J.
Warde, Charles S., Staten Island, N. Y.
Welch, J. Alfred Mrs., Methuen, Mass.
Wakefield, F. M. Mrs., Syracuse, N. Y.
Whittemore, W. F. Mrs., Leicester, Mass.
Winslow, A. M. Mrs., Waltham, Mass.
Weaver, Frank L., Lowell, Mass.

LIST OF EXHIBITS AT THE CONVENTION.

In Charge of Mr. Henry F. Jenks, Pawtucket, R. I.

Union Water Meter Co., Worcester, Mass., Water Meters, etc.
Hersey Mfg. Co., Boston, Mass., Water Meters.
Builders' Iron Foundry, Providence, R. I., Venturi Water Meters and castings.
Thomson Meter Co., Brooklyn, N. Y., Water Meters.
Neptune Meter Co., New York City, Water Meters.
Buffalo Meter Co., Buffalo, N. Y., Water Meters.
National Meter Co., New York City, Water Meters.
Coffin Valve Co., Neponset, Mass., Valves, Hydrants, etc.
Ross Valve Co., Troy, N. Y., Pressure Regulating Valves, etc.
Kennedy Valve Mfg. Co., New York City, Valves.
M. J. Drummond, New York City, Testings Plugs and Service Boxes.
B. C. Smith, New York City, Pipe Cutting Machine.
A. P. Smith Mfg. Co., Newark, N. J., Tapping Machine.
Rensselaer Mfg. Co., Troy, N. Y., Valves, etc.
Daniel A. Streeter, Waterbury, Conn., Pipe Plugs.
Eagle Oil and Supply Co., Boston, Mass., Metal Polish.
Henry F. Jenks, Pawtucket, R. I., Drinking Fountain.
Lead-lined Iron Pipe Co., Wakefield, Mass., Lead-lined Pipe.
Crosby Steam Gage and Valve Co., Boston, Steam Gauges and Valves.
H. R. Worthington, New York City, Water Meter and Pumping Eng. Model.
Holly Mfg. Co., Lockport, N. Y., Photographs of Pumping Machinery.
Ashton Valve Co., Boston, Steam Gauges and Valves.
Ashcroft Mfg. Co., New York City, Steam Gauges, etc.
R. D. Wood & Co., Philadelphia, Pa., Drawings of Hydrants, etc.
Deane Steam Pump Co., Holyoke, Mass., Steam Pumps.
Fall River Iron Works, Fall River, Mass., Service Boxes.

OBITUARY.

RICHARD R. YATES.—Died Sept. 10th, 1896, aged 62 years. Joined the Association, June 18th, 1885.

Mr. Yates was Superintendent of the Northboro, Mass. Water Works for many years.

CHAS. B. BRUSH.—Died June 3rd, 1897, aged 49 years. Joined the Association, June 16th, 1886.

Mr. Brush graduated as civil engineer from the New York University in which he was for several years a professor of civil engineering. He afterwards devoted himself to a general engineering practice and made a brilliant record as an engineer, being chief engineer of the Hoboken Land and Improvement Co., the North Hudson County Railway Co., the Hoboken Ferry Co., and the Hackensack Water Co. He was a member of many scientific societies, including the American Society of Civil Engineers and the American Water Works Association.

Mr. Brush contributed a valuable paper to this Association on Aeration and Filtration, published in Vol. II., No. 1, p. 71.

JOSEPH A. LOCKWOOD.—Died August 24th, 1897. Joined the Association, Sept. 14th, 1887.

Mr. Lockwood graduated from Union College as a civil engineer, and had been superintendent of the Yonkers, N. Y. Water Works for 25 years.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XII. December, 1897. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

LOSS OF PRESSURE CAUSED BY METERS IN FACTORY FIRE SUPPLIES.

BY E. V. FRENCH, MECHANICAL ENGINEER, BOSTON, MASS.

[*Read Sept. 8, 1897.*]

OBJECT.

The tests described in this paper were made under the auspices of the Factory Mutual Fire Insurance Companies, with the generous cooperation of the Naumkeag Cotton Mills, and the Salem (Mass.) Water Works. and others named below. Their main object was to determine the loss of pressure caused by meters, especially with reference to their use on fire service pipes, and to determine the safest form of meter for this kind of work. The work was all carried on under the general direction of Mr. John R. Freeman.

In the matter of water meters on large fire pipes the interests of the insurance companies and water departments sometimes seem to conflict.

Commonly when starting anew the pipe systems can be so arranged as to provide a small separate pipe into the mill yard for its regular supply for domestic and manufacturing purposes which can be metered while a separate pipe is run for fire purposes alone, which is so simply arranged and with so small possibility of draft that no meter is needed, and more than nine-tenths of the factories insured

in the Factory Mutuals thus find no necessity for use of meters. But there are places where meters on fire supplies appear to be a necessity. We have, therefore, thought that to lay our data before you, thereby making clear the causes of our objections to meters, might encourage the production of some sort of a metering device capable of thoroughly guarding the interests of Water Departments but free from the impairment of fire protection presented in greater or less degree, by all existing meters.

It may be well for the sake of completeness, to briefly restate the insurance companies objections to meters on fire pipes—these are:

1st. Meters obstruct the flow of water, thus lessening the efficiency of fire streams. Many common types of meter that are excellent for accuracy of metering so obstruct the flow as to reduce the pressure under ordinary fire conditions more than one-half.

2nd. The moving parts of many meters in common use, may become so stuck by a stick or stone coming along in the water, as to absolutely prevent the flow of enough water to be of any service whatever for fire work. Moreover, when meters remain idle for long periods, as is often the case on fire pipes, the ordinary sediment in the water is sometimes sufficient to cause sticking.

3rd. The fish-traps necessarily used with most meters, while lessening the danger of the moving parts of the meter becoming blocked, are, themselves always liable to become clogged by pipe scales, leaves, and other similar stuff in the water. This is especially the case with meters on fire pipes, for the draft of water caused by a fire is likely to be so much larger than the normal draft, that it stirs up much sediment which remains quiet in the pipe with ordinary flows.

We have always advised that meters on fire services for those cases where meters absolutely can *not* be avoided, be placed in a by-pass with a gate in the straightway connection which is to be opened in case of a fire, but sealed shut at all other times. While we believe this to be the proper arrangement and worth its cost, it does not furnish a reliable remedy to the above troubles, for in a number of instances in our own experience, such by-passes have been absolutely forgotten in the excitement of a fire. Several of these cases, moreover, happened in plants where the care given to the fire service was excellent in every respect. Only recently one of our inspectors opened four 1-inch streams in a mill yard when the pres-

sure dropped from 70 to 33 pounds; the superintendent then *remembered* that there was a 4-inch meter on the 6-inch supply pipe. When the by-pass was opened the pressure rose to 51 pounds. Many of you will also recall the several examples of similar experiences given by Mr. Freeman in his remarks on this subject at the Hartford convention.

4th. Large meters with necessary gates and fittings, are very expensive and add a considerable percentage to the cost of a mill fire system. As often the amount of money available for such a system is limited, this results in a cutting down of the useful apparatus purchased and a replacing of it by something which actually lessens the efficiency of that which remains.

METERS TESTED AND TIME AND LOCATION OF TESTS.

In addition to the meters designed especially for fire pipes, and therefore designed to give large flows with small losses, a number of other types of meters were tested in order to get fairly complete data on the principal types of meters used, with the idea of getting comparisons and ascertaining what *not* to use on a fire pipe.

The following meters were tested :—

Meters Designed for Large Flows with Small Loss of Pressures :

METERS ADAPTED FOR FIRE SERVICE

Tested at Salem, July, 1896 :

4-inch "Gem" meter, manufactured by National Meter Co.
6- " " " " " " " "
4- " "Torrent" meter, manufactured by Hersey Mfg. Co.
8- " " " " " " " "

Tested at Philadelphia, August, 1897 :

6-inch By-pass with 2-inch "Crown" meter in the straight pipe.
4- " " " 1½- " " " " " " "
6- " Pratt & Cady check valve with 2-inch "Crown" meter around the check.

The last three meters were made up from ordinary pipe fittings by the Bureau of Water, Philadelphia.

METERS DESIGNED FOR VERY ACCURATE REGISTRY OF FLOWS, LARGE AND SMALL, BUT NOT FOR SMALL LOSSES OF PRESSURE:

NOT WELL ADAPTED FOR FIRE SERVICE.

Tested at Salem July, 1896:

4-inch "Crown" meter, manufactured by National Meter Co.
4- " "Hersey" " " " Hersey Mfg. Co.
4- " "Lambert" " " " Thomson Meter Co.

Tested at Lowell, September, 1897:

4-inch "Union" meter, manufactured by Union Meter Co.

Tested at Salem, July, 1896.

3-inch "Worthington" meter, manufactured by Henry R. Worthington.

The Worthington meter was obtained from the meter department of the City of Boston, through the kindness of Mr. John R. Murphy, water commissioner, the other meters were freely loaned by the manufacturers.

For the Salem tests, we are indebted to the Naumkeag Steam Cotton Co., for the free use of their yard, piping and general facilities, and to the Salem Water Board, who, through their superintendent, kindly granted us the use of the city water. The Lowell tests were made in the yard of the Lawrence Mfg. Co., where every facility was given us. Water from the reservoir of the Proprietors of the Locks and Canals was generously granted by their agent.

The Philadelphia tests were made through the kindness of Mr. John C. Trautwine, Jr., chief of the bureau of water, Philadelphia, and Mr. A. J. Fuller, assistant engineer, who freely granted us full use of their testing apparatus and also gave us the benefit of their tests and investigations on proportional or by-pass meters.

In carrying on these tests the larger part of the observations and computations were made by Messrs. F. M. Herrmann, A. L. Kendall and H. O. Lacount of the Inspection Department of the Factory Mutuals.

METHODS OF TESTING.

Plates I and II show the general arrangements of meters, gages, etc., for testing.

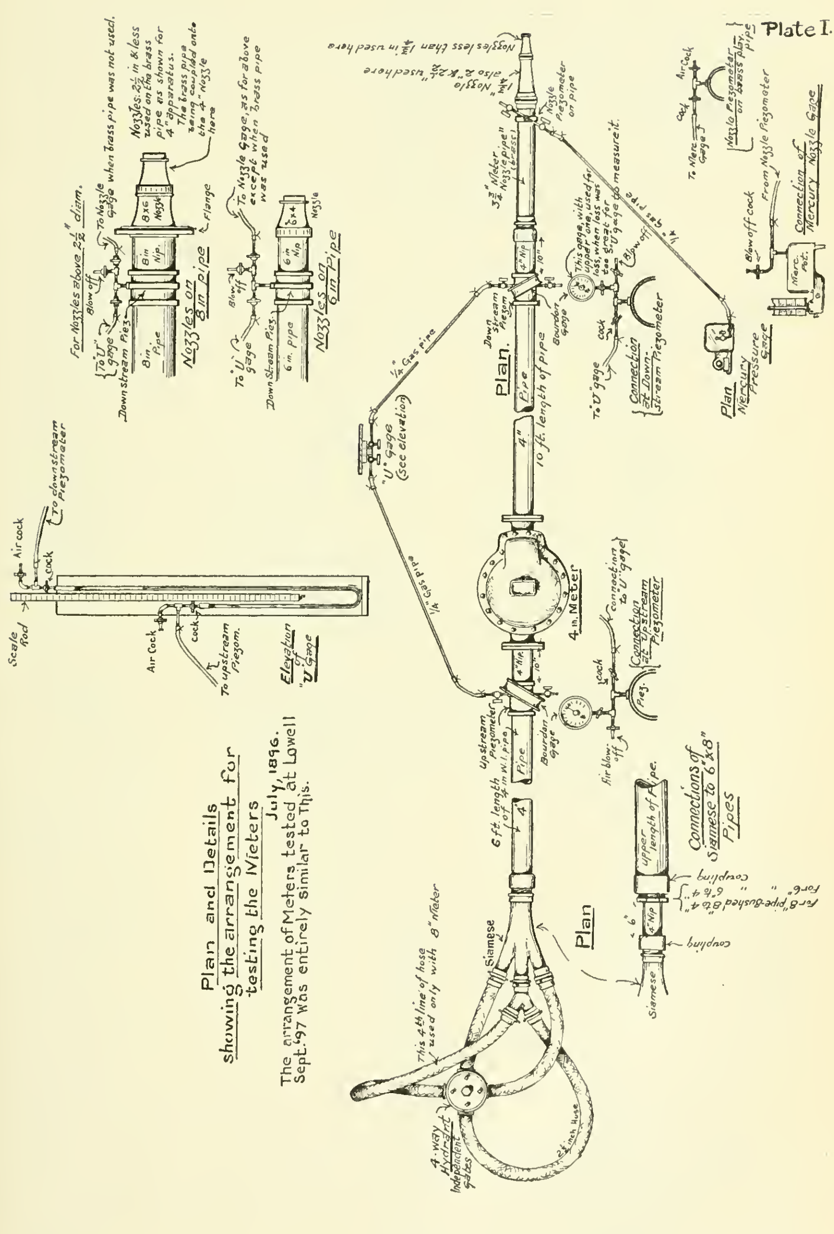
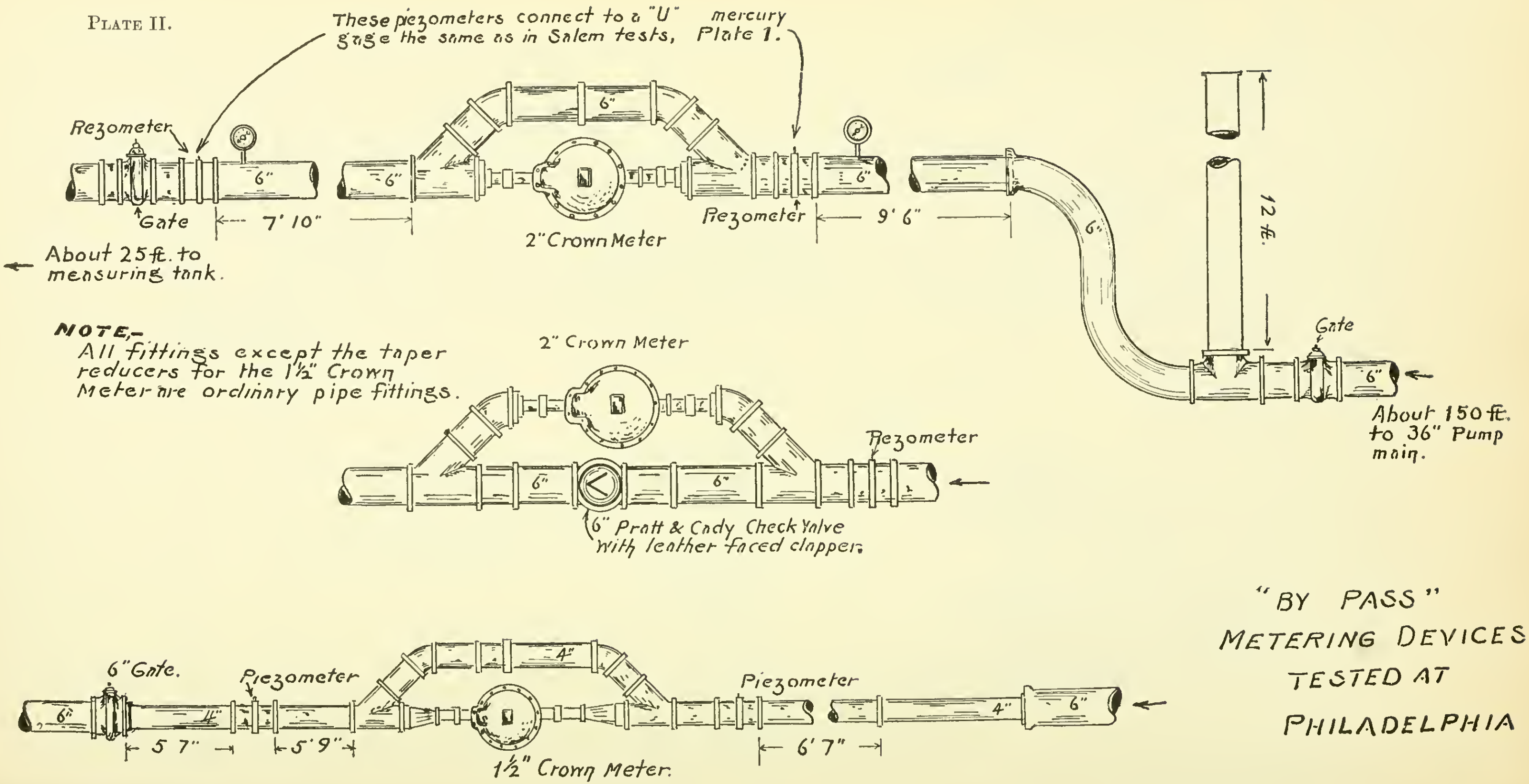


Plate I.
Plan and Details showing the arrangement for testing the Meters
July, 1896.
The arrangement of Meters tested at Lowell Sept. '97 was entirely similar to this.
Elevation of "U" Gage
Scale Rod
Air cock
cock
Air Cock
To downstream Piezometer
To upstream Piezom.
Nozzles on 8 in. pipe
For Nozzles above 2½" diam.
Blow off
To Nozzle Gage when brass pipe was not used.
Nozzles 2½ in. & less used on the brass pipe as shown for 4" apparatus. The brass pipe being coupled onto the 4" Nozzle here
Down stream Piez.
8 in. Pipe
8 in. Nip.
8x6 Nozzle
Flange
To "U" gage
Nozzles on 6 in. Pipe
To Nozzle Gage, as for above except when brass pipe was used
Down Stream Piez.
6 in. Pipe
6 in. Nip
6x4
Nozzle
Plan
4-way Hydrant Independent Gates
2½ inch Hose
This 4th line of hose used only with 8" Meter
Siamese
6 ft. length of 4 in. W.I. pipe
Upstream Piezometer
Bourdon Gage
Air blow-off
cock
Piez.
Connection at Upstream Piezometer
connection to "U" gage
4 in. Meter
¼" Gas pipe
"U" Gage (see elevation)
10 ft. length of pipe
Plan.
Down Stream Piezom.
4" Nip
10"
3½" Meter Nozzle pipe (brass)
Nozzle Piezometer on pipe
1¼" Nozzle also 2" & 2¼" used here
Nozzles less than 1¾ in. used here
This gage, with upper one, used for loss, when loss was too great for "U" gage to measure it.
Blow off
To "U" gage
Connection at Down Stream Piezometer
Plan Mercury Pressure Gage
Merc. Pot.
Blow off cock
From Nozzle Piezometer
Connection of Mercury Nozzle Gage
To Merc. Gage
Nozzle Piezometer on brass pipe
Connections of Siamese to 6" x 8" Pipes
Siamese
coupling
For 8" pipe Bushed 8 to 4"
For 6" " " 6 to 4"
upper length of Pipe

PLATE II.


These piezometers connect to a "U" mercury gage the same as in Salem tests, Plate 1.
Piezometer
Gate
6"
7' 10"
About 25 ft. to measuring tank.
2" Crown Meter
Piezometer
9' 6"
12 ft.
Gate
About 150 ft. to 36" Pump main.
NOTE,-
All fittings except the taper reducers for the 1½" Crown Meter are ordinary pipe fittings.
2" Crown Meter
Piezometer
6" Pratt & Cady Check Valve with leather faced clapper.
6" Gate.
Piezometer
4"
5 7"
5' 9"
1½" Crown Meter.
Piezometer
6' 7"
"BY PASS"
METERING DEVICES
TESTED AT
PHILADELPHIA

Just up stream from the meters was placed a piezometer with from seven to ten feet of straight pipe back of it, so that the water might enter it without whirls and eddies. Down stream from the meter a similar length of straight pipe was placed for the same purpose, to the end of which was screwed the second piezometer. A quarter-inch pipe was then carried from each piezometer to the "U" tube Mercury gage. With this arrangement the readings of the "U" gage gave directly the loss of pressure between the piezometers. The actual loss caused by the meter was that read from the "U" gage less a slight correction for the friction in the straight pipe between the piezometers. In the few cases where the loss exceeded the range of the Mercury gage, ordinary Bourdon pressure gages were used.

In the Salem and Lowell tests, the quantity of water flowing was measured by meter nozzles, according to the methods developed by Mr. John R. Freeman, (See Trans. Am. Soc. C. E., 1890) as well as by the meter under test. The nozzles used were of the smooth type and varied in diameter of outlet from ½-inch to 5 inches. For very small quantities, ⅛, ¼ and ⅜ inch holes in thin brass plates were used. In the Philadelphia tests the quantity flowing was measured in a large tank with a swinging spout attachment, the depth of which was accurately determined by a hook gage.

Most of the nozzles used had been very accurately calibrated by Mr. Freeman in his experiments at Lawrence and Nashua, so that the quantities by the nozzle may be considered as certainly accurate within about 1 per cent, and probably correct within one-half of 1 per cent. About the same degree of accuracy was obtained at Philadelphia.

In making a test, water was allowed to run for a few minutes before observations were commenced to allow all to come to normal conditions. In most of the Salem tests at a given signal the meter was read and half-minute readings commenced on the "U" gage and on the Mercury nozzle gage. The meter was also read each minute, thus giving a record of the uniformity of flow. At the end of a definite number of minutes, the meter was again read, on signal, and the test stopped. From the average of the nozzle pressures the rate of flow in gallons per minute was computed, and from the average "U" gage readings the loss of pressure corresponding to this flow determined.

In the later tests the exact time in which the meter registered an even number of cubic feet, was noted with a stop-watch, the nozzle measurements being made the same as before. This latter method is the better one as it is free from errors caused by inaccuracies in the graduations of the meter registers, and as it is easier to operate a stop-watch when a dial hand reaches a certain point than to catch the exact reading of a moving meter on signal. With the first method however, the quantities run were generally so large that any errors from these causes would be very small in percentage. When the tank was used instead of the meter nozzles, the rate of flow was found by dividing the total gallons caught in the tank by the time of the test, all other observations being the same as before.

With the ordinary meters the chief point sought was the loss of pressure with various flows, with the meters in various conditions, though the data obtained gave considerable interesting information as to the accuracy with which the meters registered. With the proportional meters the friction loss was also obtained, but in addition the co-efficient by which the reading of the small meter must be multiplied to give the total quantity was carefully determined. In the tests with the tank, the total cubic feet caught in the tank divided by the cubic feet registered by the small meter gives the co-efficient.

RESULT OF TESTS—FRICTION LOSS.

The main results are given in Table I, and are plotted in Plates III and IV. Tables II and III simply give the data of Table I in another form.

From Table I, we find, for example, taking a flow of 500 gallons per minute, or two good, stiff $1\frac{1}{8}$-inch fire streams, which is more than a 4-inch pipe would be called on to supply ordinarily the following losses of pressure due to the meter:

In a	4-inch "Hersey"	Meter	40	pounds.
"	4-inch "Crown"	"	31	"
"	4-inch "Lambert"	"	13	"
"	4-inch "Torrent"	"	8	"
"	4-inch "Union"	"	6.4	"
"	4-inch "Gem"	"	4	"
"	6-inch "Gem"	"	1.1	"
"	8-inch "Torrent"	"	0.7	"

TABLE I.

Loss of Pressure Caused by Meters.

Gallons per Minute Flowing Through Meter.	Equiv. No. of 250 Gallons Fire Stream.	Loss of Pressure in Pounds due to the Meter.											
		Current Meter.		Disc M't'r	Rotary Piston.			Current.		Proportional.			Piston.
		4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in. By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass 1½ in. Crown	Worthington.
50	......	...	.	....	0.3	0.5	..	...	....	....	0.1	0.1	1.6
100	.....	..	0.2	0.6	1.4	1.6	0.2	..	....	....	0.1	0.2	6.0
200	. ....	0.8	1.3	2.2	4.9	6.1	1.1	.. .	..	. .	0.2	0.5	23.0
250	1	1.1	2.0	3.4	7.5	9.3	1.7	....	....	0.1	0.3	0.8	34.8
300	......	1.6	2.9	4.8	10.9	13.3	2.5	0.4	0.3	0.1	0.4	1.1	48.0
400	.... .	2.7	5.1	8.2	19.9	25.1	4.2	0.8	0.5	0.2	0.6	1.9	.. .
500	2	4.1	8.1	12.9	31.2	40.0	6.4	1.1	0.7	0.3	0.8	2.9	....
600	.....	6.1	11.9	18.7	...	....	9.4	1.7	1.0	0.5	1.1	4.4	....
700	.....	8.3	16.4	25.1	...	....	12.8	2.3	1.3	0.7	1.5	6.1	....
750	... 3	9.5	18.9	28.6	....	....	14.6	2.6	1.6	0.7	1.7	7.2	....
800	......	10.8	21.4	....	..	....	16.6	3.0	1.8	0.9	2.0	8.3	....
900	......	13.5	...	...	...	.	20.8	3.9	2.3	1.2	2.5	10.9	...
1000	4	....	..	..	....	...	25.5	4.8	2.8	1.4	3.0	13.9	....
1250	5	...	...	....	..	....	..	7.2	4.5	2.3	4.8	...	....
1500	6	...	...	....	..	....	....	10.0	6.4	3.1	7.1	....	....
1600	.....	...	...	....	...	....	....	...	7.3	3.5	8.6	...	....
2000	8	...	...	....	...	....	....	....	...	5.6	..	....	.
2500	10	....	....	...	...	....	....	....	...	....	...	.	...

The Gem, Crown and Hersey meters had fish traps as a part to the meter, so that the losses above includes the trap. The Torrent, Lambert, Union and Worthington meters use a separate trap; they were however tested without traps.

TABLE II.

Equivalent Pipe Losses. (Meters in Normal Condition.)

	4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass $1\frac{1}{2}$ in. Crown.	3 in. Worthington.
Approximate feet of new, straight, clean, cast iron pipe that would cause the same loss of pressure as the meter.	45	80	130	310	385	67	180	425	58	122	32	625

The Worthington Meter was an old one and therefore not fairly comparable with the new clean meters.

TABLE III.

Losses Caused by Meters at Different Velocities.

Velocity Feet per Second in Pipe Size of Meter.	Pounds Loss in Pressure Caused by Meters.											
	4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in. By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass $1\frac{1}{2}$ in. Crown.	3 in. Worthington.
5	0.70	1.2	2.1	4.8	6.0	1.0	0.90	1.75	0.3	0.6	0.5	7.5
$7\frac{1}{2}$	1.55	2.8	4.7	10.7	13 3	2.4	2.15	3 92	0.6	1.4	1.0	16.5
10	2 60	4.9	8.0	19.4	25.0	4.0	5.00	7.00	1.1	2 4	1.8	28.0
$12\frac{1}{2}$	4.00	7.8	12.8	31.1	39.8	6.2	5.70	.....	1.8	3.6	2.7	41.4
15	5.80	11.8	18.5	.....	....	9.2	8.00	...	2.5	5.4	4.2	.....
20	10.20	20 4	.....	...	.....	16.0	.....	...	4.4	. .	8.0	....

Plate III

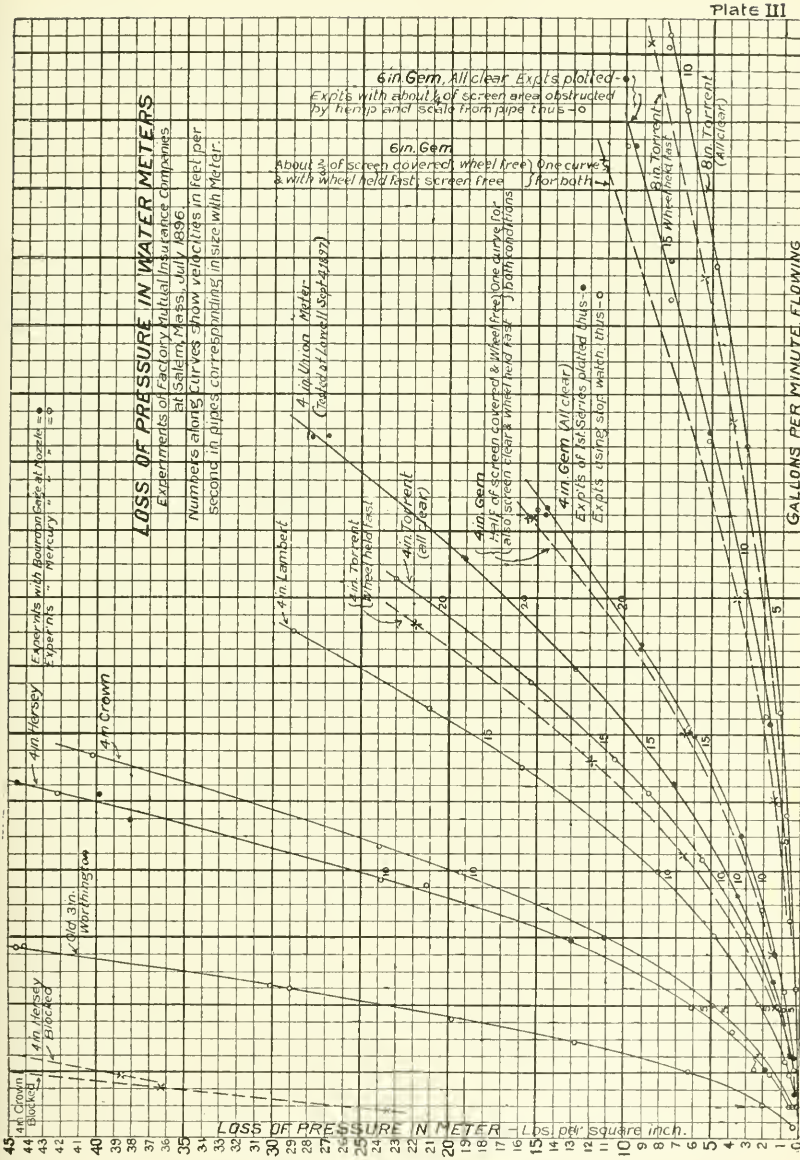
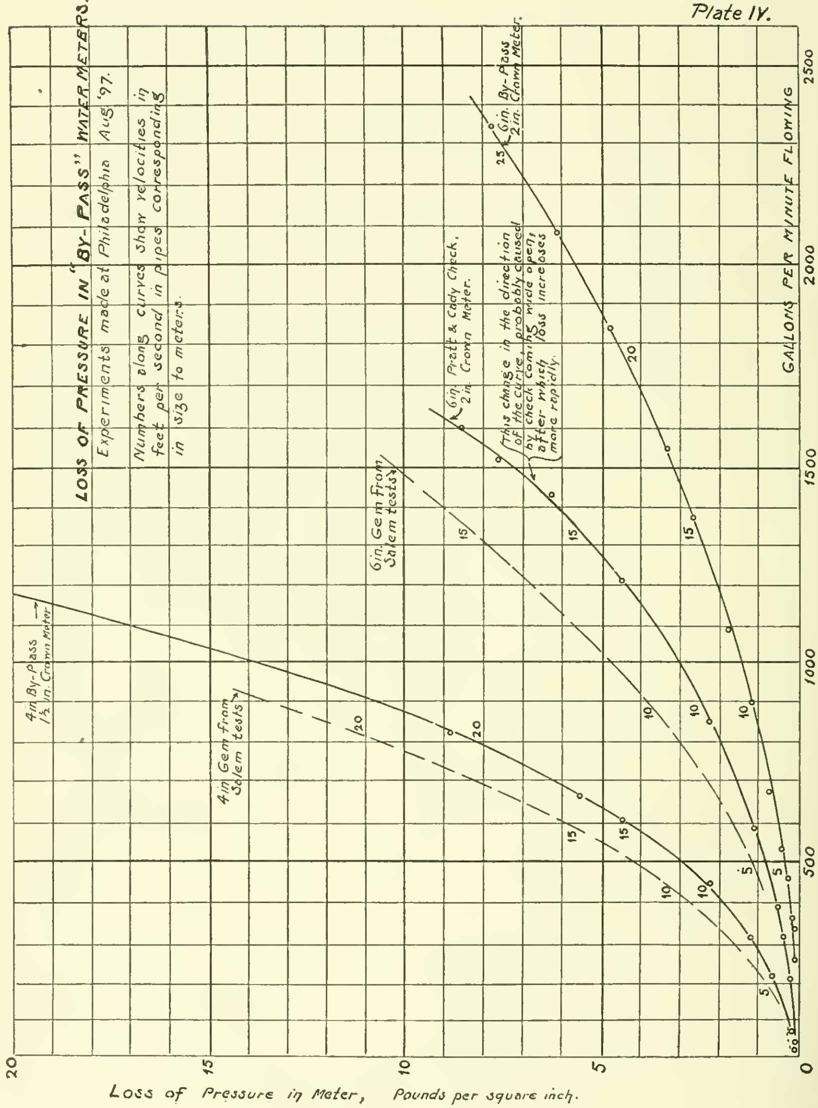

LOSS OF PRESSURE IN WATER METERS
Experiments of Factory Mutual Insurance Companies at Salem, Mass., July 1896.
Numbers along curves show velocities in feet per second in pipes corresponding in size with Meter.
Exper'nts with Bourdon Gage at Nozzle = •
Exper'nts " Mercury " " = o
4 in. Hersey
4 in. Crown
Old 3 in. Worthington
4 in. Hersey Blocked
4 in. Crown Blocked
4 in. Lambert
4 in. Union Meter (Tested at Lowell Sept. 4, 1897)
4 in. Torrent (Wheel held fast)
4 in. Torrent (all clear)
4 in. Gem
Half of screen covered & Wheel free
also screen clear & wheel held fast
One curve for both conditions
4 in. Gem (All clear)
Expt's of 1st Series plotted thus-•
Expts using stop watch thus-o
6 in. Gem, All clear Expts plotted-•
Expts with about ¼ of screen area obstructed by hemp and scale from pipe thus-o
6 in. Gem
About ⅔ of screen covered; wheel free
& with wheel held fast; screen free
One curve for both
8 in. Torrent 15 Wheel held fast
8 in. Torrent (All clear)
GALLONS PER MINUTE FLOWING
LOSS OF PRESSURE IN METER — Lbs. per square inch.

Plate IV.


LOSS OF PRESSURE IN "BY-PASS" WATER METERS.
Experiments made at Philadelphia Aug '97.
Numbers along curves show velocities in feet per second in pipes corresponding in size to meters.
4 in. By-Pass
1½ in. Crown Meter
4 in. Gem from Salem tests
6 in. Gem from Salem tests
6 in. Pratt & Cady Check.
2 in. Crown Meter.
This change in the direction of the curve, probably caused by check coming wide open, after which loss increases more rapidly.
6 in. By-Pass
2 in. Crown Meter.
GALLONS PER MINUTE FLOWING
Loss of Pressure in Meter, Pounds per square inch.

Again, taking 1000 gallons per minute or four good $1\frac{1}{8}$-inch streams, we have the losses as follows:

In a 4-inch "Union"	Meter	25.5	pounds.
" 4-inch "Gem"	"	16	"
" 6-inch "	"	4.8	"
" 8-inch "Torrent"	"	2.8	"

It is to be kept in mind that a 4-inch meter would in practice seldom or never be called on to deliver so much, 1,000 gallons per minute. But these figures are instructive in showing the great difference in friction loss in meters of different types.

In a subsequent test of a number of the meters the moving parts were securely wedged in place so that they could not move, thus representing the conditions when a stick or stone gets into a meter. The results were as below:

In the 4-inch "Gem"	Meter,	blocking increased	the friction	about	10	per cent.
" 4-inch "Torrent"	"	"	"	"	15	"
" 6-inch "Gem"	"	"	"	"	20	"
" 8-inch "Torrent"	"	"	"	"	20	"

The "Crown," "Hersey," "Union," "Lambert" and "Worthington" meters can be blocked in such a position that but little water can pass through them, so that under these conditions they would practically *destroy* a fire service.

These results clearly show up the obstruction caused by meters. It is to be remembered that these figures were obtained with new meters, and everything free and clean; that time would increase the loss of pressure caused by a meter there can be no question. While the losses in the "Gem" and "Torrent" meters are not excessive, it is well to remember that many of the city and town water supplies are at a pressure which can be considered as only moderate for fire streams, therefore, the desirability of avoiding every pound of unnecessary loss in getting the water from the city or town mains to the nozzle of the fire stream, and it is also to be remembered that their apertures are liable to be suddenly obstructed by the gravel stone, stick, eel scale or other foreign material stirred up and brought along with the rush of water caused by the fire draft.

FISH-TRAPS.

In the Salem tests the water used was taken from a 4-way hydrant at the end of several hundred feet of 10-inch yard pipe which had been recently laid—this 10-inch pipe connected with the city mains.

After the first heavy draft of water through this pipe, which occurred with the 6-inch "Gem" meter, when about 1,500 gallons per minute were drawn, *it was found that in this brief period about three-quarters of the surface of the screen in the fish-trap was covered with hemp, pipe-scale and mud*, closing about from one-fourth to one-third of the area.

To get an idea of the effect of partial blocking of the fish-trap, one-half of the screen in the trap of the 4-inch "Gem" meter was covered by a board, in which condition it was found that the loss through the meter was increased about 10 per cent., or about the same as if the trap was free and the wheel blocked. In the 6-inch "Gem" meter, two-thirds of the screen was blocked by a board and the loss thereby increased about 20 per cent., which happens again to be about the same as for the blocking of the wheel.

The area of the screen in the trap for the 4-inch "Gem" meter was about 2.8 times the area of a 4-inch pipe.

The screen for the 6-inch "Gem" trap was about 3.2 times the area of a 6-inch pipe.

The short time which it took when first testing the 6-inch "Gem" meter to obstruct one-third of the screen area, would indicate that in case of the long draft of a severe fire a very serious blocking would be entirely possible; this, however, of course depending much on the care in laying the pipe to keep all obstructions out of it and the frequency with which the mains were thoroughly blown off.

Our experience with screens on the suctions of fire pumps gives further emphasis to this point. While with the ordinary drafts of water—such as when the fire pump is occasionally used at slow speed for boiler feeding or similar work during the time the regular pumps are being repaired—no trouble whatever may be noticed, though the strainer is half covered by grass, gravel or scale; but let the extreme quantity needed for fire fighting be called for and there is dangerous inability to get a full supply.

The fact that obstructions in pipes may remain unnoticed with ordinary drafts and are likely not to be discovered till the heavy draft of a fire calls attention to them, is further illustrated by a

fire which occured some time ago in one of New England's large manufacturing plants, where, after the fire, an important gate was found to be open only about two inches. Again, when the Union Station in Providence burned a year or so ago it was found when, *after* the fire, the cause for weak streams was being looked into, that a main 16-inch gate was shut, the water or at least a part of it, having to reach the fire through a circuitous 6-inch pipe.

With such meters as the "Gem" or "Torrent" where the blocking of the moving parts is not serious, it would be better as far as a fire service is concerned to omit the fish-traps entirely; this is, however, objectionable as without traps there would be danger of drawing a stone or stick into the revolving parts and breaking them every time a large quantity of water was drawn. This, in fact, happened in Salem when testing the 8-inch "Torrent" meter, as no fish-trap was used with it,—a small stone lodging between the guides and the revolving turbine, breaking several buckets. With the proportional type of meter the fish-trap would of course be on the small meter and entirely unobjectionable.

With the above facts in mind, can it be wondered that those who are responsible for the protection from fire of properties whose values often run into the millions, look with serious apprehension at the installation of meters on the fire service pipes.

Drawing from Mr. Freeman's remarks at Hartford, already referred to herein, we do not believe that, except in rare cases, the men who manage the large factory industries of the country would purposely steal water for the sake of saving its cost. That employees may ignorantly or for their convenience, draw water from hydrants, sprinkler blow-offs, or similar outlets on fire systems, is a possibility. In most mill fire systems the piping is laid out in such a simple and direct manner that it is easy for the water works inspector to make himself reasonably sure that no water is being improperly used. If surreptitious use or hidden connection is feared a short $\frac{3}{4}$-inch by-pass may be tapped in around the main gate into the yard, and a $\frac{3}{4}$-inch meter kept set in this by-pass. Then occasionally without warning let the water works inspector shut the main gate for ten minutes and see if the meter moves. This will detect any hidden connection. Moreover, it is entirely feasible to seal the hydrants and blow-off gates on the sprinkler systems, using a lead seal similar to that universally employed on

freight-cars. Such a seal can be easily broken in case of fire, but will prevent any draft of water through the ordinary channels without giving clear evidence of the fact.

Such arrangements as the above necessitate absolutely separating fire supply pipes from those bringing water for manufacturing purposes. In general, however, a pipe much smaller than the fire pipe which may be equipped with any meter the water department desires will furnish all the water used for manufacturing and can be put in at a cost that is entirely reasonable. This is certainly better for the water departments than to use a large meter on the fire main, as a smaller meter allows a closer registering of the quantity used.

ABILITY OF LARGE METERS TO DETECT SMALL FLOWS.

In those few cases where the interest of the water department seems imperatively to require a meter on the fire service pipes, we have heretofore advised the "current" type of meter, such as the "Gem" or "Torrent," and occasionaly find that the superintendents of water departments feel that they are not safe even with these meters from the fear that their large capacity renders it possible to draw considerable quantities through them without registering. To see how serious this matter was we carefully experimented with the large capacity meters to see just where their limit of sensitiveness came. The following results were obtained:

The 4-inch "Gem" meter with $8\frac{1}{2}$ gallons per minute flowing did not register. The wheel was then started by opening some extra cocks thus allowing a larger flow, but when the cocks were closed it stopped again. With 19 gallons per minute flowing the meter registered at the rate of a trifle over 17 gallons per minute. The 4-inch "Torrent" meter with 11 gallons per minute flowing registered at the rate of about 10 gallons per minute. The 6-inch "Gem" meter with 11 gallons per minute flowing, did not register and the wheel did not continue to move at this quantity even after being started by increasing the flow. With 13 gallons per minute flowing, the meter registered at the rate of 4 gallons per minute and with 22 gallons flowing, at the rate of about 19 gallons per minute.

The 8-inch "Torrent" meter with $8\frac{1}{2}$ gallons per minute flowing, registered at the rate of 2 gallons per minute. With 20 gallons per minute flowing, at the rate of about 18 gallons per minute. These

tests were made with the small orifices in thin brass plates, pressures at the orifices being in the neighborhood of 60 pounds.

These results show that the amount of water drawn, where the pressure is good and the service pipes are of liberal size, by an ordinary $\frac{5}{8}$-inch sink tap, or by an ordinary garden hose with $\frac{3}{8}$-inch nozzle, would be registered with tolerable accuracy by a new 6-inch "Gem" or new 8-inch "Torrent" meter, but that about half of this rate of flow could be drawn without registering. A discharge of a single automatic sprinkler would be well registered.

The piston and disc meters can detect and measure considerably smaller flows. The 4-inch "Union" meter was the only one which was specially experimented with as to sensitiveness. With this meter the flow through a $\frac{1}{8}$-inch sharp edged hole in a thin brass plate under 90 pounds pressure, or about 2.8 gallons per minute was the lowest which would move the meter. The meter recorded about one-half of this flow, the other half being leak. With a $\frac{3}{8}$-inch orifice, under 5.4 pounds pressure, giving 5.7 gallons per minute, the meter was about 16 per cent behind in quantity. With the same orifice as 15 pounds, giving 9.6 gallons per minute, the meter was about 5 per cent slow.

With the 4-inch "Lambert," "Crown" and "Hersey" meters, $8\frac{1}{2}$, $14\frac{6}{10}$ and $21\frac{5}{10}$ gallons per minute, respectively, were the smallest quantities drawn, the meters registering these flows satisfactorily.

We made no tests on the "Venturi" meter, as this has been very fully reported upon by others. The loss caused by this meter is so small as to be practically unobjectionable. The meter may, however, introduce an obstruction if the brass lining of the throat is not made long enough, from tubercles forming on the unprotected iron near the throat and choking the passage. This trouble can of course be easily remedied by extending the lining on both sides of the throat for a liberal distance. Large "Venturi" meters, it is understood, cannot satisfactorily measure very small flows.

In the Philadelphia tests the by-pass arrangements experimented on, were those which the Philadelphia Department had found after a good many experiments, gave the best results. Their data being freely open to us, made it possible to quickly come to conclusions as to these devices, thus saving us a large amount of experimenting. The results were as follows: With the 6-inch by-pass and 2-inch

"Crown" meter it was found impossible to keep the meter moving with a total flow less than about 250 gallons per minute. With a 4-inch by-pass and $1\frac{1}{2}$-inch "Crown" meter, about 45 gallons per minute was the lowest quantity we succeeded in registering. These results cannot be considered satisfactory.

Table IV and Plate V give the co-efficients by which the readings of the small meter must be multiplied to give the total quantities, and show that with larger quantities these devices can measure with tolerable accuracy. If with the 6-inch by-pass the co-efficient be taken as 29 the greatest deviation from the co-efficient, found experimentally, would be about two, over a range from 500 to nearly 2500 gallons per minute. This would mean at the worst point an error of about $6\frac{1}{2}$ per cent in the quantity measured.

With the 4-inch by-pass with from 200 to 1800 gallons per minute flowing, the average co-efficient would be about 16, the maximum found in the experiments being a trifle over 17, and the minimum a trifle over 16. The maximum error being about $6\frac{1}{2}$ per cent as before.

As the whole idea of the proportional meter is to create a loss of pressure between the points of connections of the small meter, it was thought that possibly the check valve, ordinarily necessary in a factory fire service to keep the fire pump water off of the public mains, might be used instead of a by-pass to cause this necessary loss of pressure, thus making unnecessary any additional obstruction. The use of a check valve for this purpose was also suggested by Mr. Crandall in his paper before this association, read February 10th, 1897.

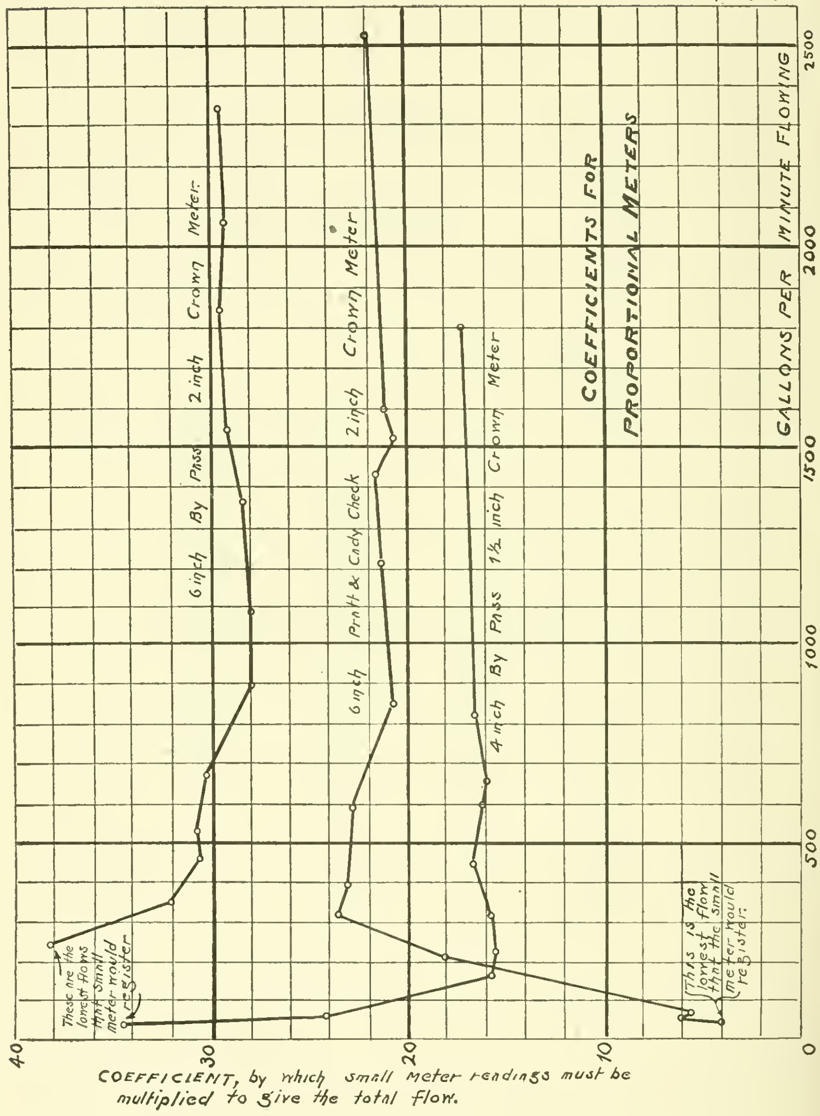
With a 6-inch Pratt & Cady check valve, with leather faced clapper and a 2-inch "Crown" meter in a by-pass around the check, we found about 45 gallons per minute, the lowest flow which would keep the small meter running. With this flow the co-efficient was about four. It rose rapidly to about 23 at 300 gallons per minute, the average being then about 22 from 300 to 2500 gallons per minute. The maximum co-efficient found was $23\frac{1}{2}$, the minimum $20\frac{1}{2}$, giving curiously about $6\frac{1}{2}$ per cent as the maximum error as with plain by-passes. While these results are not especially satisfactory, it would seem that the idea has very hopeful prospects of development.

TABLE IV.

Co-efficients for By-Pass Meters.

Rate of total flow in Gallons per minute.	Co-efficients by which readings of small meters must be multiplied to give total quantities passing.		
	6 in. By Pass. 2 in. Crown.	6 in. Check. 2 in. Crown.	4 in. By Pass. 1½ in. Crown.
10	....	...	...
15	....	....	....
20	....	....	....
30	....	....	....
40	....	4.0	34.5
50	....	6.0	28 0
75	....	6.0	22.5
100	....	8 0	20.8
150	....	12.2	16.5
200	....	16.8	15.5
250	38.0	20.0	15.5
300	35 0	22.7	15.7
400	31 3	23.1	16.4
500	30.8	22 9	16·5
600	30.6	22.9	16.1
700	30 0	22.0	16 1
800	29 0	21 1	16.5
1000	28 0	21.0	16.6
1200	28.2	21 3	16.7
1400	28.8	21.6	16.8
1600	29.3	21.1	17.0
1800	29.5	21.2	17.1
2000	29.3	21.4	...
2200	29 3	21.6	...
2400	29.5	21.8	....
2600	....	22.1	....

Plate V.



COEFFICIENTS FOR
PROPORTIONAL METERS
GALLONS PER MINUTE FLOWING
6 inch By Pass 2 inch Crown Meter
6 inch Pratt & Cady Check 2 inch Crown Meter
4 inch By Pass 1½ inch Crown Meter
These are the lowest flows that small meter would register
This is the lowest flow that the small meter would register.
0
500
1000
1500
2000
2500
40
30
20
10
0
COEFFICIENT, by which small meter readings must be multiplied to give the total flow.

If in some way *which could not possibly endanger the full opening of a check valve* a slight *initial stick* can be given to the clapper, *all* the water at small flows would be forced through the small meter, thus bringing the sensitiveness of the whole device down to that of a 1 or 2-inch meter of the best type. With large flows, the check would open, and a quantity would be measured on the proportional plan. Mr. Freeman some years ago proposed a check valve with a weighted clapper for this purpose, but has not found time to work out the idea in practical shape to his satisfaction, but it appears entirely practicable.

In Mr. Crandall's paper it is suggested that the spindle of the clapper be carried through the valve casing, and an outside weighted lever attached, with the weight so arranged that it will be thrown off when the valve opens. The possibility of dangerous sticking of the spindle, or of the external lever becoming carelessly blocked by some obstruction in the valve pit, would make this arrangement a little open to suspicion. It would seem, however, that these dangers could be gotten over and a satisfactory solution of the problem found after due study, and we shall be much pleased if some member of this society will work out the details of such a device.

In most fire systems it is illegal to draw *any* water except for fire, when the quantity used is not cared for, without notifying the water department. It would, therefore, seem that the check valve arrangement would put about as useful information into a superintendent's hands as if he could swear to the exact quantity used, i. e., if he was sure of the *fact* of sinning, the *degree* of it would be of minor importance.

This device, besides its action as a *detector*, would, however, give some idea of the degree, though it has one curious quality in which it resembles the general idea of the working of our common law in that it jumps hardest on the man who does not steal enough. If, for instance, only a small quantity is taken, i. e., not enough to overcome the initial stick of the clapper, and then the water department figures the bill, using the average co-efficient of 20 or 30, the mill will certainly pay a fine rather than a water bill, while if a large quantity was stolen, the fine element would disappear.

This might lead to disputes, but as the law had been broken anyway, the offending one would have little ground to stand on. The weighted lever arrangement, moreover, with the falling off weight

mentioned by Mr. Crandall, suggests the possibility of some sort of a recording device which would show if the clapper moved from its seat.

Such an arrangement would seem to give us a device absolutely unobjectionable to insurance companies, but one which would appear to give complete protection to water departments.

The use of the meter nozzle gave a means of learning the average accuracy of the various meters tested. In general, it was found that meters of the current type, with flows slightly above the minimum mentioned, measured the water within from three to four per cent of the truth, and often closer, though occasionally a somewhat larger deviation would be found. With the disc and piston meters tested the average accuracy was from one to two per cent. These results would seem to be good enough when measuring a liquid no better than water.

CONCLUSION.

In conclusion, our position on meters, with the devices *now* obtainable in the market is this :

1st. We should earnestly advise that *every other means* for safe guarding the interests of the water department be exhausted before resorting to meters.

2d. Where meters are unavoidable, we should urge the use of the current type, such as the "Gem" or "Torrent."

(a) Because the loss of pressure caused by these meters is moderate.

(b) Because if their moving parts become stuck the friction loss is not seriously increased.

3d. We do not consider the ordinary types of disc or piston meters at all suitable for fire pipes from the fact that they can almost completely stop the flow, if their moving parts become blocked.

4th. In cases where meters must be used, we should advise that they be placed on a by-pass, with a gate in the straitway connection. This straitway gate should be provided with an indicator post, and if possible, the meter should be so placed that this post will be in a conspicuous location. It is also a good plan to put gates in the by-pass, on each side of the meter, so that it may be examined or repaired without shutting off the fire service.

DISCUSSION.

THE PRESIDENT. The paper is now open for discussion. Is there any one who noticed anything in the paper with which he did not quite agree, or is there some meter man who can tell us how to remove the obstruction, or possibility of obstruction, that exists in connection with his particular type of meter? It seems as though there must be something to be said in the discussion of this paper, which will be of interest to us all.

MR. FRENCH. Mr. President, I should like to learn the general opinion of the superintendents as to how much value this sort of detector idea would have. That is, if you had an arrangement which would simply give you the information that *some* water had been drawn, wouldn't that, in a great many cases, be all you would care to know? This is a problem on which we find you have a good deal more to say when we come to meet you individually, and want certain things done, than you seem to be willing to say this afternoon, but we would like to get what ideas we can from you now, for it may help us later on. We imagine that with the attempts that now seem to be made everywhere to reduce waste, perhaps the fire service pipe would be jumped upon about as soon as anything, although, as I have said, our experience would indicate that they are not a very great cause of waste. We want to get at just what is really necessary for the protection of that sort of a service. You see our idea of the subject, anyway.

MR. FISH. Is it a fact that fire service pipes in New England are generally metered?

MR. FRENCH. We have very few meters on fire pipes, and have always taken the ground strongly that they should not be there; but we do find every now and then a desire, and perhaps it is increasing, to put meters on, and occasionally we find a place where it is impossible for us to convince the superintendent that a meter should not be put on. A very small percentage of our factory sprinkler and yard hydrant fire services are metered, probably not one in twenty, but still there are enough to make it somewhat of an important question with us.

MR. FISH. It is novel to me that they have meters for fire services.

Mr. French. Perhaps I should explain that, the properties which the Factory Mutuals are principally interested in are similar to the large mills at New Bedford, Fall River, Lowell and Lawrence, where they have a large mill yard, and very often an 8, 10 or 12-inch connection, from the city service right into the yard, and a complete system of fire hydrants and automatic sprinklers, independent of the supply for manufacturing purposes. Check valves are placed in these connections so that the mill fire pumps cannot pump back into the public mains. It is the general custom for the mills to allow the water works inspector to enter the yard at any time, and to see just exactly what is going on. In some cases, where there seemed to be cause for suspicion, the water department has sealed all the blow-off gates, each hydrant, and the valves controlling the sprinklers. It is understood, of course, in these cases that the fire system is entirely separate from the supply for mill use, so that excepting in case of fire there is no occasion for any draft from it whatever.

The President. Is there any superintendent here who has meters on fire service pipes, who would like to say something on this subject? I don't like to call upon anybody by name, but I will ask Mr. Walker if he has ever had any experience in that direction. (Applause.)

Mr. Walker. As far as fire pipes are concerned, I confess that sometimes one feels as if he would like to have them metered. For instance, you have a mill where there are pipes for fire purposes only, they will take the city water to fill their boilers with occasionally, and use it generally as they see fit. We had one case in Manchester where, unfortunately, their reservoir was lower than ours, and on one occasion when something ailed their pumps, they opened the gate and filled up their reservoir from ours. There wasn't any meter in use there. Where the supply comes right from the city, I am satisfied that there ought to be something done to meter those places. The insurance men want a 12-inch pipe for a 50-foot mill. (Laughter.) They want to cover it all over with sprinklers; naturally, they don't want any loss. They are very anxious, and they have a great deal of information on these subjects, and they tell us just how big a pipe is needed for this and that, wherever they have any insurance on property. (Laughter.)

A gentleman came to me last year and said he was going to try the hydrants in his yard and wished me to come down or send a man. He was a pretty good sort of a fellow, and he wouldn't open them without my permission. He said, "I have made up my mind I am not going to put anything new in, and if the insurance company won't insure the mill as it is now, it needn't insure it at all, and I will do it myself." These insurance men come around and look at your plant and tell you what you ought to have done, so really the superintendent hasn't much to say about it. They generally take all the measurements, and tell the superintendent what kind of pipe they want in such a street, where a new depot is going up, or a new mill, or something of that kind. I am not prepared to talk on this subject, but I should really like to talk on it about half a day (laughter), because I have been afflicted somewhat by these insurance fellows. I guess, however, I won't air my grievances this afternoon, because I haven't got in very good shape what I would like to say. But I am satisfied of this much, that some kind of a meter—I shan't recommend any particular kind, for they all go back on me at times, as I have said before—but I am satisfied that there should be some kind of a meter on all fire services so that the mills can't steal the water. The bigger the company the more it will steal. (Laughter.)

THE PRESIDENT. I would like to ask Mr. French if he does not consider that there is a large loss of water on account of fire sprinklers, which cannot be attributed at all to fires? For instance, in a factory in Lynn I have understood that on an average nine sprinklers burst in a week; and whenever a head bursts it necessitates the running of the full amount of water contained in the pipes at times. And it does seem to me that there must be a large use of water on account of these fire sprinklers that we don't know anything about. It goes into the general consumption, the 40 or 50 per cent of water we pump that doesn't do anybody any good. And while this does not really enter into the question of the use of meters on the fire service generally, if we had meters on the sprinkler service they would pay for the amount of water that they use when there is no fire, and which really is quite an important factor, in my opinion, in the water works supply. I would like to ask Mr. French if it is not a fact that there is a large amount of water wasted, owing to the irregular working and repair of these points?

Mr. French. In answer to Mr. Haskell—I assume he means water wasted by the breaking open of an automatic sprinkler when there is no fire.

I am sure Mr. Haskell has been misinformed about the danger of heads opening when there is no fire, and that nine breaks in the whole city of Lynn for a year would be more likely the case. Moreover, of these breaks, many would be from accidental blows and therefore instantly discovered, and very few would open of their own accord. In the properties insured by the Mutual companies there are over two million (2,000,000) sprinkler heads, but our experience is that the loss from water damage is almost nothing. We do have sprinklers break open, but the loss caused is very, very small, and considering the immense number of sprinklers that we have, the breaks are very, very infrequent. I know in Lynn, because my home is there, there have been one or two, perhaps more unfortunate cases of sprinklers breaking in shoe factories, and the break not being discovered for some time. But in the Factory Mutual work every plant has a watchman, often more than one watchman, so that the bursting of a spinkler is generally discovered promptly. In fact, so low has been the loss from sprinklers that to allay the fears of some of the mill people, when asked to put sprinklers over valuable parts of their plants, two of the largest Mutual companies have taken up sprinkler insurance, that is, they insure against water damage from the accidental bursting open of sprinklers and fire protection pipes and have found the actual losses to be insignificant. It is probably within the truth to say that less than one sprinkler in fifty thousand of the better types breaks open accidentally in the course of a year. I am positive that the waste of water from the breaking of automatic sprinklers is of no importance whatever.

The President. As I understand the value of an automatic sprinkler, it is simply to effect one purpose, and that is to stop a fire right at its inception. These sprinkler heads are distributed through the factory, and if the heat at any one point gets above a certain degree, the sprinkler operates. Immediately a certain amount of water escapes, but no greater amount of water passes through the pipe than can pass through one sprinkler, which, in the case of a 6-inch meter, would be an almost infinitesimal amount.

My object in making this explanation is this: I think all super-

intendents will agree with me that it certainly would be proper to pay the city for all the water used to keep these pipes in order. I do see force in the argument that we ought to supply these sprinklers with water for fire purposes, the same as we supply water to the hydrants for fire purposes. Where a city gives water for fire purposes to a hydrant free of charge, perhaps they might be expected to do so to fire sprinklers, from the fact that a small amount of water used by the fire sprinkler to extinguish a fire, would save a large amount which would have to be used later in case the fire broke away. But the principal objection I saw, or the two objections I saw, as the paper was read, which the sprinkler people make to the use of meters on their pipes, were: first, that they reduced the pressure of the water; secondly, that it might be possible for an obstruction to stop the flow of water entirely. Now it occurs to me that there is little water used by a fire sprinkler until its point of efficiency is passed. I consider that a fire sprinkler is a very good thing until the fire department gets there; the moment the fire department gets there it is worse than useless, it does not help the fire department a great deal in putting the fire out, and, consequently, there are only, perhaps, one or two, or three, or at the most, five minutes, when the fire sprinkler is expected to do any work. If that is the case, with the amount of water that can flow through these one, two, three, four or five points, it would not effect the efficiency of the sprinkler at all to have a 4-inch or a 6-inch meter on the supply. That is the way it looks to me, but I should like to get a little information from Mr. French in that direction.

MR. FRENCH. There is no doubt whatever that the introduction of automatic sprinklers lessens the total consumption of water for fire purposes if you have a small brief fire to fight instead of a large fire lasting for hours. The amount of water drawn by the ordinary automatic sprinkler at 60 pounds pressure is in the neighborhood of 45 gallons a minute with no allowance deducted for pipe friction, but under ordinary conditions of pipe friction the discharge from a dozen sprinklers equals the discharge from one hose nozzle. Now it is true, as Mr. Haskell said, that in a great many cases one or two sprinklers open and put out a fire. When that happens the fire department generally finds very little to do. In our fire reports, averaging more than a fire a day, we are all the time finding fires reported where two or three heads have opened and the fire has been

extinguished. Perhaps the department has had to put on a hose stream to get into a corner somewhere, but the fire was practically put out by the sprinklers.

Now in small buildings or with ordinary contents, it is true that there would commonly be only a comparatively small number of heads open. But in cotton mill work the tendency is towards very large areas. In New Bedford there are mills five or eight hundred feet long, and 125 to 140 feet wide. In such a mill it is almost impossible to reach the center with a fire hose stream, so that in such places we look upon the automatic sprinklers as our main reliance for putting out a fire, and we feel that there is always a chance that perhaps 50 or 100 heads may open. We have had several fires in Picker rooms where twenty-five or thirty sprinklers opened in the first few minutes of the fire, and before hose streams could be put on. This was not where the pressure was feeble but where it was especially strong and able to supply large quantities without much reduction in the mains. In these cases the sprinklers did hold the fire and practically extinguished it. The only reason that so many heads opened was the quickness of the spread of the fire over loose, combustible stock. We have also had cases where seventy-five or more heads have opened.

Besides the wide buildings, there are high buildings which are sometimes quite wide besides, five or six stories and 100 feet in width not being uncommon. Here a fire in the center of the top story is very inaccessible to hose streams, so that the sprinklers are the chief reliance.

I think it will be evident to all, that any meter which in such cases cuts off several and often many pounds pressure, may seriously lessen the efficiency of the sprinklers and greatly increase the chances of a serious fire. Moreover, perfectly possible obstructions may increase the normal losses greatly or even cut off the supply entirely with some meters.

Our whole tendency is toward more liberal pipe sizes for sprinklers, meaning a chance to use larger quantities of water and within a year or two, Mr. Freeman, has advised, and there has been adopted by our companies, a schedule of more liberal pipe sizes, so that where eight or ten sprinklers are in line the most distant heads will get a good supply of water; while with the old sizes, if you open that number of heads in a line, the most distant ones will absolutely fail to get enough water to do more than drip a liberal drip.

Under these conditions you see the absolute necessity for a first-class supply. And then, remember also, that the sprinklers are the things which are working while the fire is being discovered, that is, before it is discovered, or while the department is getting there; and you will see why we feel more and more desirous, as time goes on, to make the sprinklers efficient whether few or many open at the start. In fact, our whole experience is that the very low cost of insurance in the Mutual companies is in a very large measure, due to the good work of automatic sprinklers.

THE PRESIDENT. I would like to ask Mr. French, allowing that meters are to be used, if it would not be possible to use a proportional meter, and use that with perfect safety, as far as reducing the pressure would go on the main flow of the water, even if some obstruction got into the proportional meter?

MR. FRENCH. I am very glad to have that point brought out. The proportional meter comes about as near not being a meter as anything we know of, and therefore it is the thing we like better than anything else. It, of course, puts no positive obstruction in the pipe, simply creating a little friction which operates the little meter. Now the question is, would you, superintendents, be satisfied with the proportional meter? It seems to me, as I understand your position, and I should very much like light on this point, that what you fear is the stealing of the water through the fire service pipes, either purposely or through misunderstanding. Well, now, if that is what you want to guard against, it is not going to be 500 gallons a minute, but perhaps 10 gallons a minute, or 15, or 20, and I should suppose that what you needed was something which would absolutely tell you about that thing. When it comes to larger quantities, they would hardly be used anywhere except for fire purposes, and you don't care about those. You don't charge a man for water for fire purposes, because if he don't put a fire out you have to go there and do it through another department of your government. The important thing is to prevent the stealing of water, and that is where the check valve idea seems to present a good many possibilities.

The check valve meter can be a cheap device. It gives you a proportional meter, and if you get something which will hold the clapper on the check down tight until there was a flow of 15 or 20 or 50 gallons a minute, you force all your water through the little meter and measure it accurately, but when the larger flow comes, as

from a fire draft, the check will open, and everything go on freely under ordinary conditions, or with the loss of only one or two pounds pressure, and no chance for clogging small orifices or stopping the flow entirely. Your little meter in the by-pass will meanwhile work on the proportional plan, although not recording the whole, but under those conditions you wouldn't care so much how much water was drawn. Ordinarily that little initial sticking of the check valve caused by weighting it would throw all the water to the small meter, and if you had a 10-inch service pipe, that some insurance man had somehow or other got laid into a large factory yard, you would be absolutely metering it. That is, you would have a meter on there which would be just as sensitive as if you cut that 10-inch pipe right off and put a 1-inch meter in its place. It would seem as if that would give you just the information you want, for you could go to a man and say, "You have no right to use this fire service, for you haven't had a fire, but your meter shows you have been drawing the water." He says, "How much have I drawn?" You can say, "That is not the question. You are not allowed to draw any," or you could state that at least the amount drawn was the full amount registered, and that if he had drawn it at a rate rapid enough to exceed the capacity of your (let us say) 1½ inch disc meter he had drawn in excess of the registry. And it would seem to me in that way you could keep guard over the fire system, that your interests would be absolutely looked out for, and that would be one point in your system that you knew was safe.

Mr. Fuller. I would like to ask Mr. French whether a large number of small meters would not give more satisfactory results than one large meter, whether the registration would be any better?

Mr. French. Of course if you had a 6-inch pipe and put in eight or ten 2-inch Disc meters you would reduce the friction to a point where even an insurance man could hardly object to it. And, moreover, by having so many openings you would, of course, very much reduce the danger of the meter becoming stuck. That is, it is very improbable that four or five would get stuck at the same time. When it came to measuring the small flows, and that is the thing I suppose you are most interested in, it would seem to me you would get no more sensitiveness than with a big meter, for the water would simply gradually find its way through each of the meters, and probably none of them would register much of anything.

SINKING FUND TABLES.

BY F. L. FULLER, C. E., BOSTON, MASS.

[Read Sept. 8, 1897.]

As the payment of many water works debts is provided for by means of a sinking fund, it may be interesting to show how the amount required for yearly payments may be determined.

A sinking fund is ordinarily made up of annual contributions or payments, which with their accumulated interest, shall, at the end of a certain period, pay the debt for which the fund was formed.

It is evident that the longer the term which the sinking fund has to run, or in which to mature, the smaller the annual payments will be, both on account of more numerous payments and of larger accumulations of interest. Thus the annual contribution which will be necessary to pay a debt of $10,000 in ten years at four per cent, compounded semi-annually, is $799.08, while to pay the same debt in thirty years requires a yearly payment of only $170.24.

The following table shows what one dollar amounts to at the end of each six months up to the end of four years, when put at interest at four per cent and compounded semi-annually :

At time of deposit	$1.000
" end of 0 years and 6 months	1.02
" " 1 year	1.0404
" " 1 " and 6 months	1.061208
" " 2 years	1.08243216
" " 2 " and 6 months	1.1040808032
" " 3 years	1.126162419264
" " 3 " and 6 months	1.14868566764928
" " 4 years	1.1716593810022656

A similar table can be computed for any other rate, compounded either annually or semi-annually.

At the present time, four per cent, compounded semi-annually, is the common rate of interest for sinking funds.

From a table similar to the above, and computed for a period of thirty years, and carried out to a proper number of decimals, can be constructed a table showing the result of depositing or paying in one dollar each year and allowing it to go on interest at the rate of four per cent, compounded semi-annually.

The following tables are constructed for the period of 30 years, which is as long as many sinking funds run.

From this table it appears that one dollar paid in at the beginning of 30 years, amounts to $3.28103 at the end of that time. One dollar paid in at the beginning of 29 years amounts to $3.15362 at the end of that period. One dollar paid in at beginning of 28 years amounts to $3.03117 at the end of that time, and so on till the last payment, which amounts to only $1.0404, because it is on interest only one year.

If we add the amounts together, we find that the thirty payments of one dollar, with the accrued interest, amount to $58.74219. Twenty annual payments of one dollar, with accrued interest, amount to $31.11002. Ten annual payments of one dollar with accrued interest, amount to $12.51435.

This is shown in the second column of the table, which is obtained from the first by successive additions.

Now it is evident that if one dollar paid in each year, and immediately put at four per cent interest, and compounded semi-annually, produces at the end of thirty years $58.74219, that to produce $125,000 at the end of the same time, the annual payment must be equal to $125,000 divided by $58.74219, or $2,127.94.

To produce $1,000 at the end of 30 years, the annual payment must be equal to $1,000 divided by $58.74219, or $17.0235.

To produce $1,000 at the end of 20 years, the annual payment must be equal to $1,000 divided by 31.11002, or $32.1440.

The necessary annual payment to produce $1,000 in any given number of years is given in the third column of the table, which is obtained from the second, by dividing 1,000 by the corresponding number in that column.

WELLESLEY WATER WORKS.

Table Showing Debt and Annual Contribution Required for the Sinking Fund.

F. L. Fuller, Civil Engineer, Boston.

Year in which Debt was Incurred.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Total Annual Contribution Required.
1885	$125,000	$2,127.94																													$2,127.94
1886	"	"	$5,000	$453.38	$4,000	$319.63	$5,000	$355.61																							3,256.56
1887	"	"	"	"	"	"	"	"	$7,000	$403.64	$5,000	$160.72																			3,820.92
1888	"	"	"	"	"	"	"	"	"	"	"	"	$10,000	$321 44																	4,142.36
1889	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$10,000	$321.44															4,463.80
1890	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$6,000	$192.86	$6,000	$179.60											4,836.26
1891	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$6,000	$179 60									5,015.86
1892	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"									5,015.86
1893	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$18,000	$578.59							5,594.45
1894	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$9,000	$289.29					5,883.74
1895	"	"			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$15,000	$482.16			5,912.52
1896	"	"					"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$9,000	$289.30	5,882.19
1897	"	"							"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1898	"	"							"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1899	"	"							"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1900	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1901	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1902	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1903	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1904	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1905	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1906	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1907	"	"											"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1908	"	"													"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1909	"	"															"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1910	"	"																	"	"	"	"	"	"	"	"	"	"	"	"	
1911	"	"																			"	"	"	"	"	"	"	"	"	"	
1912	"	"																					"	"	"	"	"	"	"	"	
1913	"	"																							"	"	"	"	"	"	
1914	"	"																									"	"	"	"	
1915																													"	"	

The number of years the debt has to run is shown by the ditto marks (").

Years.	Amount obtained by compounding $1 semi-annually, at 4 per cent.	Amount obtained by paying $1 annually and compounding semi-annually at 4 per cent.	Annual payment required to produce $1,000 when compounded semi-annually at 4 per cent.
1	1.04040	1.04040	961.1688
2	1.08243	2.12283	471.0692
3	1.12616	3.24899	307.7880
4	1.17166	4.42065	226.2111
5	1 21899	5.63964	177.3163
6	1 26824	6.90788	144.7622
7	1.31948	8.22736	121.5457
8	1.37279	9.60015	104.1650
9	1.42825	11.02840	90.6750
10	1.48595	12.51435	79.9083
11	1.54598	14.06033	71.1221
12	1.60844	15.66877	63.8212
13	1.67342	17.34219	57.6628
14	1.74102	19.08321	52.4021
15	1.81136	20.89457	47.8593
16	1.88454	22.77911	43.8999
17	1.96068	24.73979	40.4207
18	2.03989	26.77968	37.3417
19	2.12230	28.90198	34.5997
20	2.20804	31.11002	32.1440
21	2.29724	33.40726	29.9336
22	2.39005	35.79731	27.9351
23	2.48661	38.28392	26.1206
24	2.58707	40.87099	24.4672
25	2.69159	43.56258	22.9555
26	2.80033	46.36291	21.5690
27	2.91346	49.27637	20.2937
28	3.03117	52.30754	19.1177
29	3.15362	55.46116	18.0306
30	3.28103	58.74219	17.0235

A water works or town debt is generally made up of several issues of bonds or notes. These bear different dates, are for various amounts, and run for different periods of time.

The contribution for each issue must be computed separately and the sum of these contributions will be the annual contribution required to form a sinking fund capable of meeting the various obligations as they become due.

DISCUSSION.

THE PRESIDENT. It is well known to all of us that water works men know more about almost anything connected with water works than the financial part. The financial part of the department, the control of the sinking funds and everything in that connection, is usually turned over to some commission or some members of the

city government, and, while I suppose they always exercise good judgment in the way they handle the sinking funds, it has often occurred to me as very remarkable that it is so seldom they invest any of their funds in buying their own city's bonds. Most cities have to issue bonds, have to hire money, and I have often thought it would be a wise plan for a city to borrow of itself.

Mr. Fuller. I would like to say in that connection, Mr. President, that the sinking fund of the town of Wellesley amounts to about $60,000, and that is entirely invested in the securities of the town of Wellesley. Of course it may not be possible to continue that practice, but, as Mr. Haskell has said, I think it is a good one.

Mr. Smith. I have had some experience as water commissioner and also as water superintendent in one of our small towns, where we have a debt of $75,000. The difficulty of investing the amount of money which is required for the sinking fund, is one which is somewhat perplexing. We could not buy securities with it, because the amount was so small. We have found that the best way, in order to secure compound interest on it, is to deposit it in the savings bank. In that way we have no trouble whatever; there is no money to be handled, we put in each year just the amount of money we calculate is required to make the exact deposit in the savings bank, and we let it remain there until our bonds become due, and then we draw from the savings bank whatever money is required to pay them.

As I say, we have a debt in our town of $75,000. I was very strongly advised against establishing a sinking fund at all, and it was recommended that it would be very much wiser to have annual payments, doing away with a sinking fund entirely and paying so much a year. The difficulty there was we would have to divide our whole debt up into sums of money so small that capitalists would not care to purchase the securities. It was necessary to have our debt divided up into thousand dollars. We finally made an arrangement so our debt should become due in installments of five years each—a certain number of bonds—the first five years, the next five years a larger number, and so on. The last five years of the thirty,—they were divided into six different series,—quite a large sum would become payable, but the interest, of course, is constantly decreasing with the debt. Our act of incorporation required us to establish a sinking fund, and the fact that the bonds were not to be paid

in annual payments created a necessity for a sinking fund, and in order to provide means for paying the installments as they became due, we deposited our money in the savings bank.

MR. GILBERT. In our town we have placed the sinking fund in our own water bonds wholly. We began in that way and have always kept it up, so our sinking fund consists of our own water bonds. They pay four per cent and we have taken them at par.

MR. FULLER. I would like to ask Mr. Smith what rate of interest he gets?

MR. SMITH. We usually get four per cent, and our bonds bear interest at four per cent. I ought to say, perhaps, what I omitted to say, but my friend has brought it out by the remarks he has just made, that we virtually invest in our own bonds, because every five years we take up a certain number of the bonds. Then the next five years we have to make a deposit in the sinking fund large enough to cover the interest on those bonds we have redeemed.

MR. BEALS. I have had a little experience with sinking funds and with water debt, but not in the line of the practice of the gentleman who spoke last. I do not understand how he can get interest from a savings bank on more than $1,600, for our Massachusetts savings banks can only receive a deposit up to one thousand dollars and pay interest on sixteen hundred dollars. If they pay on more than that I suppose they are liable to be called to account by the bank commissioners. We have in our town a debt of the size he mentioned, $75,000. We commenced at first by making it payable in blocks of a certain amount at the end of each five years. After running a little while we found just that difficulty of finding an investment for our sinking funds. The savings bank would take only a thousand dollars, and we could not find investments, and we began to see thousands of dollars piling up. Now to an average water man five thousand dollars is a big sum, I mean to those of us connected with the smaller works, and we saw that the whole thing was rather a menace. There was a temptation, an itching desire, perhaps, to handle large amounts of money. And right here I may say it seems to me that the paying of a debt with a sinking fund is like constituting ourselves bankers. It is doing a double business to accomplish a single purpose. That is we reckon how much we owe, and how much we are getting in our sinking fund, and there are two funds piling up.

After running one year we found there was this temptation, the difficulty of finding investments, and the risk of having some board or commission handling the sinking fund, and necessarily some salary to be paid to somebody to handle it, which would be an expense. Our bonds were all held by one savings bank as an investment. So we obtained the permission of our fire district which owns the works, and of the bank holding our bonds, to alter our times of payment, and we made thirty different bonds, payable in different sums in the thirty years. When our act was passed we were required to establish a sinking fund, and at that time we voted to establish a fund to which we would contribute every year an amount sufficient to pay the bonds maturing at the end of each five years. We changed our bonds so that we made a bond payable every year. The first five years of the thirty we paid a thousand dollars a year. Then at the end of that time, if we had paid five thousand dollars we saved two hundred dollars in interest, and we calculated our works would be increasing in the meantime, and our receipts increase, so that in the second five years we could pay fifteen hundred dollars each year, and the third five years two thousand dollars, and I think the fourth five years we jumped to three thousand dollars, and then thirty-five hundred dollars, and then four thousand. We find we can keep a deposit of about a thousand dollars in the savings bank, but we hardly need to. We are on our twelfth year now, so we are required to put two thousand dollars into the sinking fund each year. There are two times in the year when a certain extra receipt comes to us, and we put that into the sinking fund. The first of September our bonds become due, and we draw an amount equal to the bond, and have something left all the time. Our sinking fund is never very large, and there is not the temptation for any board of officers handling a big sum of money, and we, as water commissioners and trustees of the sinking fund cannot get away with a very big sum if we wish to. We have protected the district, and got the sinking fund into a state of annual payments, where we handle only just about the money that we earn, and save, and expend towards the payment of our debt. The ordinary sinking fund is just like an individual hiring twenty thousand dollars for a certain purpose, and then going ahead and trying to lay up twenty thousand dollars somewhere else to pay what he has borrowed. He risks in two ways. He risks ever being able to pay the twenty

thousand dollars, and he risks losing the money he is laying up. It is a wise and safe rule for municipalities as well as for individuals, "If you have a dollar pay your debt with it."

Mr. Codd. I would like to ask the gentleman (Mr. Gilbert), if, when he buys his own bonds, he cancels them?

Mr. Gilbert. I will say that, unfortunately, the men who established our debt issued the bonds, so they are all payable in so many years, and therefore we are compelled to keep them.

Mr. Codd. So each year you have to raise interest on them and pay it to yourselves?

Mr. Gilbert. We clip the coupons and collect the interest ourselves. We know that is not the right way to do, but the bonds are thirty year bonds, all payable in thirty years to the amount of one hundred thousand dollars.

Mr. Hawley. It occurs to me that in issuing bonds the money is used for various purposes. Sometimes it is used for laying pipes or doing work which will last for a long term of years, and again the money is used for pumps, or for some working part, which will wear out in a shorter period of years. And yet it seems to be a rule, at least in this country, to issue bonds for a period of about thirty years, without paying any attention to the purpose for which the money is to be expended, whether it will give returns for thirty years or whether it will give returns for a longer period. I would like to ask Mr. Fuller if he has looked into this matter, and can give us any reason why this period of years is taken, instead of a period of years during which the work for which the money is spent will give a return?

Mr. Fuller. I don't know that I did take into account what the gentleman has suggested. I simply made this tabulation to cover any period from one to thirty years. Of course it could be extended to a good deal longer time by simply adding to the figures. I don't think Mr. Smith answered the question Mr. Beals suggested, with regard to amount he could put in any one bank.

Mr. Smith. I will simply say in reply to that, that the amount we are required to raise for our payments at no time exceeds perhaps twenty thousand dollars. The amount actually deposited in the savings bank I would say would not exceed at any time ten thou-

sand dollars, for the money the last year would be paid towards the debt directly, and it would not be necessary to invest it. I live in a town near a large city where we have access to six or seven different savings banks. All of them are equally good and equally safe, and by depositing a thousand dollars in each bank and allowing it to accumulate to sixteen hundred dollars, we should have in those banks the full amount of ten thousand dollars. The principle I have advocated is precisely the same as has been stated, only the periods are a little longer. If this method of investment is to be followed, it is of course necessary that the amount to be deposited should not be too large. The principle only applies to the smaller towns, where, as I may say it is almost a nuisance to manage a sinking fund.

RESULTS OBTAINED BY THE INTRODUCTION OF THE METER SYSTEM AT ATLANTIC CITY, N. J.

BY W. C. HAWLEY, C. E., ASSOCIATE MEMBER A. S. C. E.

[*Address Sept. 9th, 1897.*]

Atlantic City, N. J., is located on a long, narrow, sandy island, no part of which has an elevation of more than 12 or 15 feet above high tide. Its population ranges from 21,000 in winter to over 175,000 some days in summer. There is no manufacturing, but there are over five hundred hotels and large boarding houses, and about two hundred smaller boarding houses. There is a system of sanitary sewers, the storm water being carried off in the gutters.

In 1882 the Atlantic City Water Co., constructed a system of water works and began to furnish the city with water from the mainland, about six miles distant. From the first there was friction with the city government, and in 1888 the "Consumers" Water Co., constructed a plant and began furnishing water from artesian wells on the island. These two companies consolidated in 1893, and in 1895 both plants were purchased by the city, and have since been operated by a board of commissioners.

During the period of competition between the two companies, waste was encouraged rather than prevented. Many of the cheaper class of houses were on piles or stilts with pipes exposed underneath; and a few days of cold weather would cause an increased pumpage amounting to from 10 per cent to 30 per cent of the normal. Hopper closets were in common use, and the plumbing in a large portion of the less expensive buildings was of the poorest sort. Some meters had been used, but a large bill by meter measurement was frequently the reason for the removal of the meter, instead of the stoppage of the waste. The consolidation of the two companies made little change, as the prospect of purchase by the city was sufficient to defer all improvements.

When, on August 1st, 1895, the city took possession of the works, it was impossible to maintain a pressure of over 20 to 25 pounds during much of the summer season, and the plants were being operated to their limits. The consumption per capita ranged from 200 to over 250 gallons per day. Parts of the city had either no water mains at all, or else those in place were so small as to furnish but little supply. A large amount of pipe was needed in these districts, and when laid, more water would be needed to supply them. The problem confronting the city was either to reduce the enormous waste, or else to provide an additional supply of water, with new pumping plant and mains at a cost of at least $250,000, with the additional cost of operating and maintaining.

Mr. George T. Prince, member of A. S. C. E., who was appointed superintendent when the city purchased the works, recommended the general introduction of water meters and certain extensions of the distributing system. After consulting with Mr. Clemens Hershel, member of A. S. C. E., it was decided to spend $75,000 at once on extensions of the distributing system, and about 16 miles of new mains were laid; also to spend $25,000 in purchasing and setting water meters, the expenditure of $250,000 for a new supply, pumps, force mains, etc., being deferred until the results of the introduction of meters should be known.

The writer was appointed superintendent to succeed Mr. Prince, March 1st, 1896, just as the first of the meters were set. There were at that time about three hundred meters in service (many of them old meters, worn out and practically worthless) on a total of 3,095 taps. On August 1st, 1896, there were 1,916 meters in service on a total of 3,446 taps. August 1st, 1897, there were 2,135 meters in service on a total of 3,692 taps.

The results are shown in the diagrams. Fig. 1 shows the pumpage by months since the works have been operated. Fig. 2 is a comparison of the pumpage profiles for the years 1890–1897 inclusive. It is probable that about 10 per cent of the reduction in pumpage shown is due to improved condition of the pumping machinery and a slightly larger percentage for slip than was formerly allowed. Note should be taken of the fact that on August 1st, 1895, the number of services was 3,095. On August 1st, 1897, the number of services had increased to 3,692, or 19.3 per cent. In spite of this, and almost entirely because of the reduction of waste, the

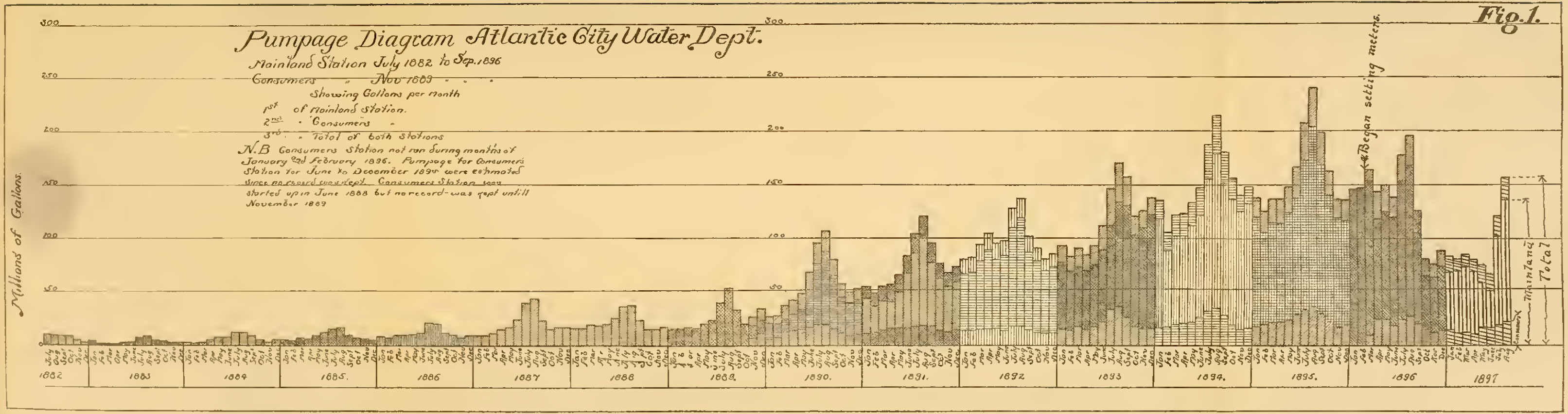
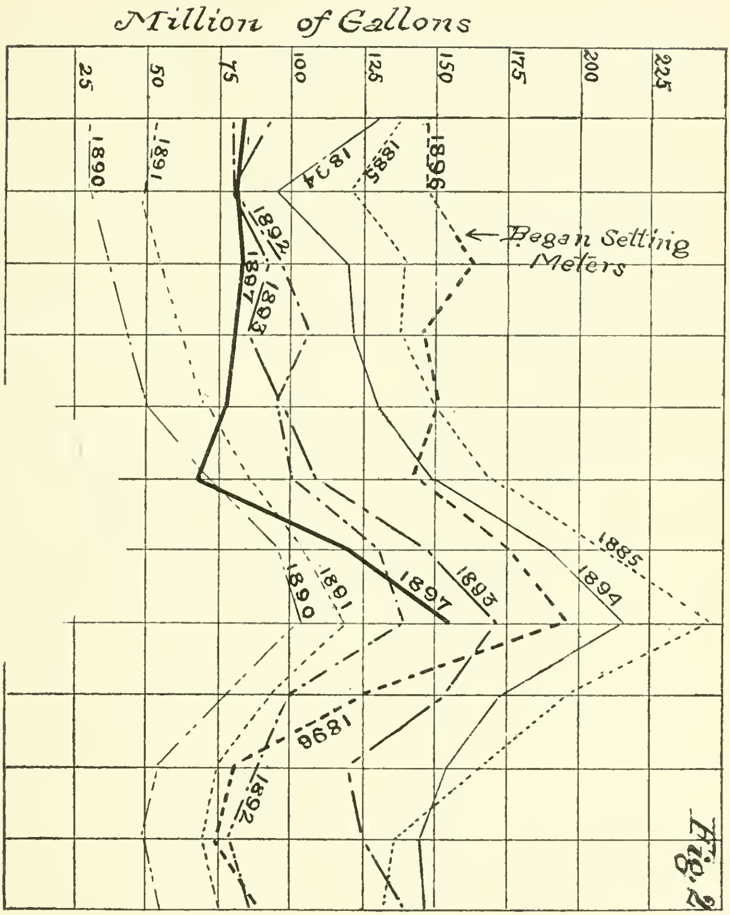


Fig. 1.
Pumpage Diagram Atlantic City Water Dept.
Mainland Station July 1882 to Sep. 1896
Consumers " Nov 1889 " "
Showing Gallons per Month
1st of Mainland Station.
2nd " Consumers "
3rd " Total of both Stations
N.B Consumers Station not run during months of January and February 1896. Pumpage for Consumers Station for June to December 1895 were estimated since no record was kept. Consumers Station was started up in June 1888 but no record was kept untill November 1889
Began setting meters.
Millions of Gallons
300
250
200
150
100
50
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
Maintand
Total

secon''
e records
ıd can not
n coal con-
page caused
August 1st,
t, 1896, to
pounds
the



pumpage shows a very marked reduction. It is true that during this period five of the larger hotels put down artesian wells for their own supplies, but the total reduction in pumpage on this account would not exceed 100,000 gallons per day; and the reduction in pumpage in August, 1897 over that of August, 1895 was 2,700,000 gallons per day. The average number of gallons pumped per tap per day in August, 1895, was 2,500. In August, 1896 this was reduced to 1,775 gallons; and in August, 1897 to 1,350 gallons, or a reduction of 46 per cent from August, 1895. This reduction in

pumpage enabled the ordinary pressure of 35 to 40 pounds to be maintained during the summer months, something which had not been done before in several years and this in spite of the large increase in the pipe system and the consequent additional consumption.

The immediate result of the introduction of meters was to defer for some years the necessity for expending for additional supply the $250,000 contemplated, thus saving the additional interest and sinking fund charges, amounting to at least $16,250 per year. THIS SAVING ALONE IN LESS THAN FOUR (4) YEARS WILL BUY AND SET A METER ON EVERY SERVICE IN THE CITY, and this allows nothing for the saving in extra labor, salaries etc., for operating the enlarged plant.

Fig. 3 shows the diagram of coal consumed at the "Absecon" (or mainland) pumping station since August, 1893. The records of the "Consumers" pumping station are incomplete and can not therefore be included. This shows a decided saving in coal consumed, due as before explained to the reduction in pumpage caused by the meters. Comparing the coal used for the year, August 1st, 1894, to August 1st, 1895, with that used from August 1st, 1896, to August 1st, 1897, there is found an average saving of 2,500 pounds (1.115 gross tons) per day, which at $3 per ton, the cost of the coal in bin, is worth $3.34 per day. or $1,220.93 per year. To this add one-sixth as much to allow for coal consumed at the "Consumers" pumping station, and the total saving is $1,424.41. The interest on the cost of these meters (including cost of setting) is $1,125 per year, so that the saving in fuel alone exceeds the interest on the cost of the meters by $299.41.

It has been shown that the number of taps increased from August 1st, 1895, to August 1st, 1897, 19.3 per cent. Had it not been for the introduction of the meter system it is reasonable to suppose that the additional fuel needed would have been at least an equal percentage, (admitting for the moment that the increased pumpage was within the capacities of the plants, which it was not). This increase would have amounted to $1,244.28 per year, to which add $299.41 (the saving per year already shown in fuel over interest) and the sum—$1,543.69 is more than enough to pay the cost of maintenance and care of the meters—which is about $1,400. This calculation has taken no account of the additional revenue received

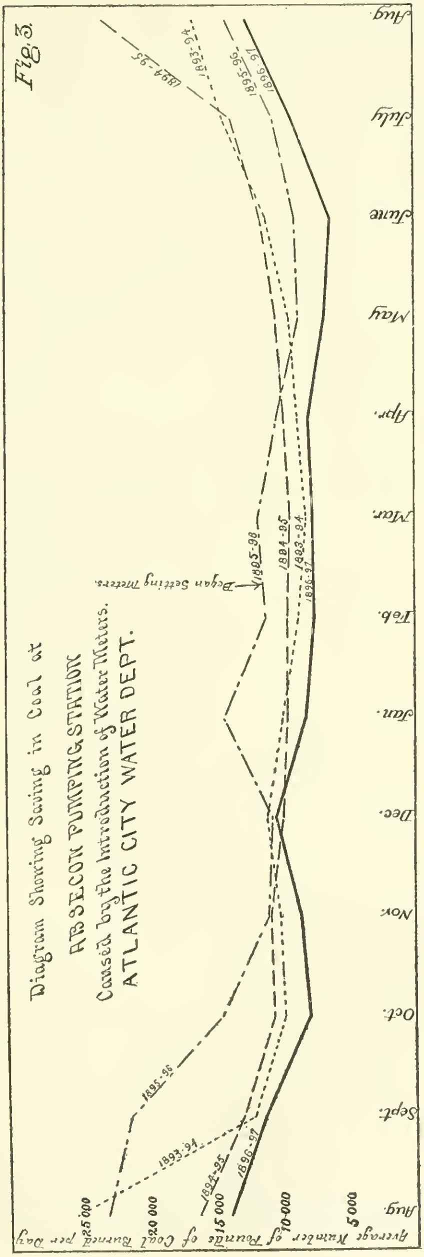


Fig. 3
Diagram Showing Saving in Coal at
ABSECON PUMPING STATION
Caused by the Introduction of Water Meters.
ATLANTIC CITY WATER DEPT.
Began Setting Meters.
1893-94
1894-95
1895-96
1896-97
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
25 000
20 000
15 000
10 000
5 000
Average Number of Pounds of Coal Burned per Day

from the 597 new services, which is easily $10,000 per year. This increase is probably offset however by the decrease in revenue due to the very general saving to the consumers on the meter rate, compared with what they formerly paid on the assessed rate. This reduction of bills has made the meters quite popular, though there is still occasionally heard the wail of some one who did not have repairs made when he should.

It becomes evident therefore, that considered solely as a cold blooded business proposition—not taking into account the equity, justice and other good reasons for its introduction—the meter system in Atlantic City has proved a success. We are now setting 1,000 new meters, and the intention is to ultimately meter every service.

The city council has decided to raise by direct taxation each year a sufficient sum to pay the water department for the water used for fire protection, street sprinkling and other public uses, thus making all property pay directly for these services, in addition to the payment for water actually used on the premises. This allows a lower meter rate than would otherwise be possible—12 cents per thousand gallons. The rates previous to August 1st, 1897, were 18 and 14 cents per thousand gallons.

In connection with this paper, the writer wishes to mention some matters which have come up in connection with the use of meters in Atlantic City which may prove of interest, and which he hopes will call forth some discussion:

First—In introducing meters generally in a city where the assessed rate has been the rule, there is bound to be more or less "kicking" on the part of those who find their bills increased when what is used is measured. This can be largely avoided, and in all fairness and reason should be.

Our meters were as a rule placed on services some weeks previous to the expiration of the term paid for on the assessed rates. Shortly before rendering the bills for the minimum rate in advance, the meters were read, and with a slide rule the number of gallons used per day on the average, for each service, was computed. This was stated on each bill, and if the amount was excessive the consumer was cautioned when he paid the bill. At the end of the first six months it was found that about one-third of the meters had registered in excess of the amounts of the assessed rates formerly paid; one-sixth were practically the same, and one-half were saving money.

Of course there were some protests, and where waste had occurred without the knowledge of the owner, some rebate was given. At the end of the first year it was found that very few still had excessive bills, they had stopped the leaks and waste, and now it is impossible to supply meters fast enough to meet the demand.

SECOND—One of the primary reasons for the introduction of the meter system is to prevent the waste of water. It is therefore desirable to locate the places where the greatest leakage or waste occurs, that such may be the first to be metered, and thus the maximum saving effected with minimum expenditure. A common opinion exists that the greatest waste occurs in the better class of buildings, where fixtures are more numerous; where lawns are sprinkled; where large washings are done; where bath tubs are frequently used, etc. Our experience in Atlantic City does not bear out this theory. We find that one leaky hopper closet (or one that is allowed to run continuously) in some small property that paid perhaps $6 or $8 per year on the assessed rate, will waste water enough to supply half a dozen fine residences, and sprinkle an acre or two of lawns besides —that the stop and waste in a cheap house where it is necessary to shut off the water every cold night to prevent freezing of the pipes, will soon wear and leak, (in this sandy soil) till five or six of them would waste enough water to do the laundry work of the town—that in cheap houses or where there is cheap plumbing, by letting the water run to prevent freezing in cold weather, enough is wasted to furnish baths galore for the whole population. In other words the great bulk of the waste is in the smaller and poorer properties. Of course there are exceptions like manufacturing plants, hotels, saloons with beer pumps, motors, etc., and occasionally we find waste in the better class of houses; but our experience indicates that with a limited amount available for meters, more waste can be stopped in tenements and the cheaper class of dwellings than anywhere else.

THIRD—What tests should be specified for water meters? Our first meters were purchased under the requirement that "no meter shall over-register, and no meter shall under-register more than two (2) per cent."

All meters of $\frac{5}{8}$-inch and $\frac{3}{4}$-inch sizes had to register on a $\frac{1}{32}$-inch stream; 1-inch on a $\frac{1}{16}$-inch stream, and larger sizes on a $\frac{1}{8}$-inch stream. Later specifications have required an average of the larger

streams down to and including the $\frac{1}{8}$-inch to be within the limits of 625 pounds and 630 pounds on a registration of 10 cubic feet, no single test to exceed the limits of + 1 % and — 2 % ($618\frac{3}{4}$ pounds and $637\frac{1}{2}$ pounds); $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters to test on $\frac{1}{16}$-inch and $\frac{1}{32}$-inch streams within + 1 % and — 5 %; the 1-inch meters to test within the same limits on $\frac{1}{16}$-inch stream; and $1\frac{1}{2}$-inch meters to test within the same limits on a flow of $1\frac{1}{2}$ cubic feet per hour. These tests are made under a pressure of 35 to 40 pounds. The testing is expensive, and it has occurred to the writer, that more simple tests might do as well, so far as practical results are concerned. Possibly on the $\frac{5}{8}$-inch, $\frac{3}{4}$-inch and 1-inch sizes a close test on a $\frac{1}{4}$-inch stream, say between the limits of 625 and 630 pounds on 10 cubic feet for accuracy; and a test on a $\frac{1}{32}$-inch stream for $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters, and on the $\frac{1}{16}$-inch stream for 1-inch meters, with somewhat wider limits, say $618\frac{3}{4}$ (+ 1 %) and 675 pounds (— 8 %) on 10 cubic feet registration for sensitiveness, would be as satisfactory as a more extended series of tests. The practical value of any test can only be told by observing the operation, in service, of the meters purchased under it.

This matter of testing meters deserves more attention than has been paid to it. A series of standard tests should be adopted and generally used. Varying conditions would have to be met by varied tests; but the conditions in this country are not so diverse but that a series of tests could be arranged which would be practical, satisfactory, and not too expensive.

Fourth—The meters in use when the city purchased the plants were practically all of the "rotary" type. The first meters purchased by the city were largely of the "disc" type, though all the $1\frac{1}{2}$-inch, 2-inch and 3-inch meters purchased were rotaries, and a few 1-inch and $\frac{3}{4}$-inch meters. It was found that the smaller rotary meters were more frequently "stuck" than the disc meters. Also that those that had been in service five or ten years were under-registering from 10 per cent to over 90 per cent; and some of them were "stuck" almost every time they were read. Several of the worst of these meters had already been repaired two and three times, at a total expense equal to if not exceeding the cost of a new disc meter. It was found that after being repaired and brought up to correct registration once, the rotary meter gets out of repair much quicker than it did the first time. The department is there-

fore spending very little money on repairs to worn out rotary meters. If simply renewing a worn out part, or some little shop work will put a meter in good condition, it is done. Otherwise it goes into the scrap heap. It is believed that considering the increasing frequency and cost of repairs to rotary meters, and the loss of revenue due to under-registration, it is better policy to replace them with disc meters than to try to keep them in repair. The disc meters cost less, and even if they show equal wear in equal time, which there is no reason to expect, the working parts can be renewed for less than the working parts of rotary meters. The friction for full flow in rotary meters is greater than that in disc meters of the same size, which is an objection where the pressure carried is low, as in Atlantic City. It is also found that the rotary meters are not as sensitive, that is will not register as accurately on the small flows, as the disc meters.

All things considered therefor, it seems best to give preference in the future to the disc type of meter in Atlantic City. Different conditions elsewhere may give different results. It would be interesting to know what results have been obtained in other places. and the writer hopes that the discussion of this paper will bring out the experience and views of others.

STEEL FORGINGS FOR PUMPING ENGINES.

BY H. F. J. PORTER, M. E.

[*Read and Illustrated by Stereopticon, Sept.* 9, 1897.]

So vast is the whole field of engineering that it is beyond the capacity of any one man to cover all of it, and so the profession is subdivided into specialties, one of the most important of which is that of the water works engineer. So comprehensive in itself is this subdivision, necessitating a knowledge of many of the other specialties, that much time and labor must be devoted to keeping up with the progress which is being made in them. If, therefore, some one who devotes his time and attention in one of these contributary directions will present to the water works engineer in a concise form some of the information that the latter would otherwise have to go possibly far out of his way to obtain, the saving in time and labor should come to him acceptably. My excuse, therefore, for drawing on metallurgical engineering for my topic must be that in the multiplicity of your other researches you might not otherwise secure in a handy form for reference the information which I will endeavor to present to you, and which I trust will be of service.

It will not be necessary for me to refer to the constantly growing responsibility which the water works engineer has to assume in designing a municipal pumping-plant. For the money it has invested freely, the public looks to him for a supply of water that never fails for even an hour.

Not only does the safety of property depend upon an efficient fire protection, but many enterprises require an uninterrupted flow of water, and health itself is assured only through the knowledge that cleanliness can be depended upon.

Every detail of your machinery must be of the most approved design and of the best material, lest it fail at a critical moment.

As our cities grow in population demands increase for larger units in our pumping stations, and it is in the nature of large pieces

NOTE.—A paper similar to the above was presented at the annual meeting of the American Water Works Association held at Denver, Colorado, June 9, 1897.

At the suggestion of several of the members of this Association, Mr. Porter was requested to repeat the paper. The paper as presented is like the original in all respects, except that a few additions have been made to the specifications quoted, bringing it up to date. [Editors.]

of metal, such as are necessary for the component parts of large engines, that, as they increase in size, they are more difficult to make with a certainty that they shall not be defective. The high duty called for in certain localities requires that all parts of such pumping-engines shall be unusually strong.

In such engines, speaking generally, all moving parts and all parts that may be subjected to alternating stresses are made of forgings, and it is to these that I desire to direct your consideration.

In the minds of those who have not given the subject some investigation, a forging is "a forging" simply. The name signifies that the piece has not been cast but has been worked up, somehow or other, under the hammer. Of what it is made, whether of iron or steel, and of what quality of either metal, seems to be of no moment.

That these unconsidered characteristics are, from the changing conditions of the times, becoming of greater and greater importance, I think I can convince you if you will give me your attention while I briefly review the history of the development of the art of forging in this country.

Up to thirty years ago wrought iron was the metal of which nearly everything in the nature of a forging was made. Rolling mills were turning out rails, structural material and merchant bars of wrought iron, and there was plenty of wrought iron scrap of good quality in the market from which forgings could be made. The industrial conditions of the country, however, were such that forges were not called upon to produce forgings of very great size. Those for which a demand was made could readily be built up by welding together small pieces of wrought iron under comparatively light hammers.

About this time, however, the large rolling mills began to change their product from wrought iron to steel, first turning out rails and structural material, later, merchant bars, and subsequently plates. As the manufacturers of the country became more and more familiar with the use of the new material, they began to appreciate that they were getting something that was stronger and more reliable than what they had been accustomed to, and. realizing that they could reduce the sizes of the forged parts of their machinery by using steel, soon began to call for steel forgings. Those that they obtained, however, were far from satisfactory, and with reason, for

the forges had not equipped themselves properly for turning them out. A little explanation may perhaps be necessary.

An iron forging is built up of small pieces and advantage is taken of the property of welding which iron possesses. A steel forging, on the contrary, has to be made from a steel casting larger than the finished piece, as steel does not possess in the same degree the property of welding. It should be, in fact, twice its size in order that the amount of work necessary to make it a forging may enter into the metal during its reduction in size under the hammer. For instance, if you should want a 12-inch shaft, made of iron, it would be built up of small pieces, 4 or 5 inches thick, welded together. If, on the contrary, you should call for a steel shaft of the same size,

FIG. 1.

best practice would require beginning with a piece of steel 24 inches in diameter and forging it down under a hammer the blow of which could be felt through 24 inches of metal instead of only 4 or 5 inches, as in the case of iron; so you can readily see that, when the manufacturers called for steel forgings, the forges did not have the hammer equipment necessary to make them, and there were many other reasons for their inability to supply what was wanted, as you will appreciate when we view the processes which are now considered necessary for turning out good work. Many forges did not hesitate to supply, however, so-called "steel forgings," and, although they have never fitted themselves up prop-

erly to this day, they have not hesitated to continue to supply the same thing ever since; but what has been supplied has not been, and cannot be. satisfactory, as I think I will make clear to you as we go further into the subject. The result is that a prejudice has unjustly been established in the trades against steel, and it has been kept fresh in the minds of the uninformed up to the present time to a great extent through these forges themselves, who have been unwilling to spend the necessary amount of money to equip themselves properly for turning out steel forgings.

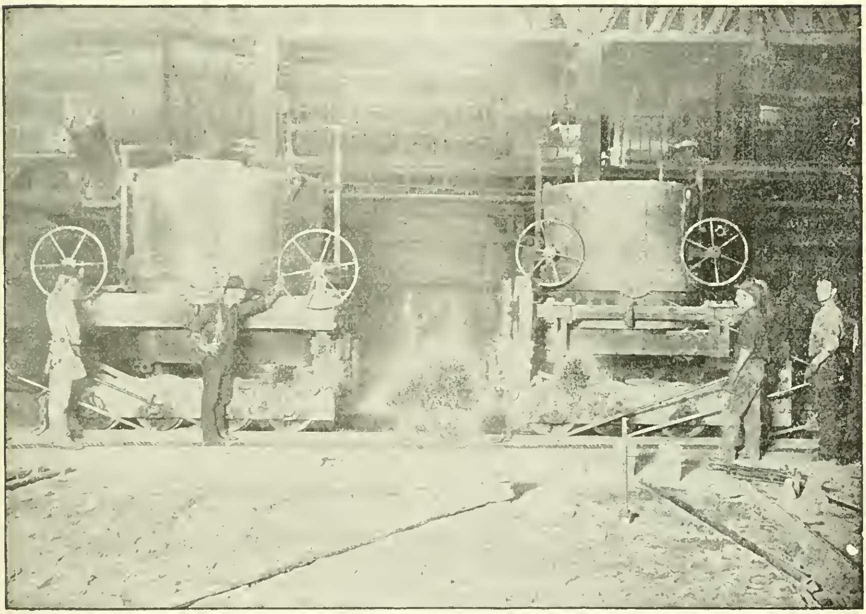


FIG 2.

Since this time, the change from iron to steel in the rolling mills of the country has become almost complete, and today wrought iron scrap is becoming more and more scarce and steel scrap more and more plentiful, so that it is with difficulty that wrought iron forges can prevent pieces of steel scrap from getting into their wrought iron forgings, for there is no way of identifying a piece of steel scrap by sight. When steel gets into a wrought iron forging, it does not weld up with it and causes points of weakness which event-

ually lead to fracture. Fig. 1 shows a wrought iron shaft broken from this cause. The piece of steel can be seen projecting from one piece of the shaft.

Good wrought iron in moderate sized forgings has an elastic limit not higher than 20,000 pounds to the square inch, on account of the large amount of slag and scale which is inherent in the metal owing to its having been puddled, in process of manufacture, in a bath of liquid cinder. Steel, on the contrary, from which the slag has escaped during its melting process, has in its mildest form an elastic limit of about 30,000 pounds, and is therefore at least one-third stronger. For these reasons steel is rapidly driving wrought iron out of the market altogether, and engineers who fully appreciate the situation have already given up the use of iron entirely. Forges are gradually equipping themselves for turning out steel forgings properly, there being one forge in this country which is probably the most complete in the world.

Let me run rapidly through the processes which are considered the best practice for turning out steel forgings.

Fig. 2 shows a small section of a furnace-plant and represents the casting of an ingot. On an elevated shelf are located a series of open-hearth furnaces to which the various ingredients of the charge to be melted are raised on hydraulic lifts. Into these furnaces (which are heated by gas generated extraneously) can be put such a composition of steel as will give the type of forging which is required for the service to which it is to be subjected eventually. Thus from ten (0.10) to fifteen hundreds (0.15) of 1 per cent of carbon make a grade of steel that differs but little in its strength from wrought iron, while an increase in its percentage up to a certain limit tends to make it stronger, and, beyond that, hard and brittle. Too much phosphorus tends to make it brittle when cold, and sulphur to make it so brittle when hot that it cannot be forged properly. Steel of high grade should have not more than .04 of 1 per cent of these elements in it. Others of its chemical constituents affect it in similar and other ways. Their combination in proper proportions can be arrived at only from long experience in constant handling, and by observing their subsequent effect on resultant forgings in actual service. From time to time, during the process of melting, a small dipperful of the molten metal is taken out of the furnace and rapidly tested, to ascertain how the refining is tak-

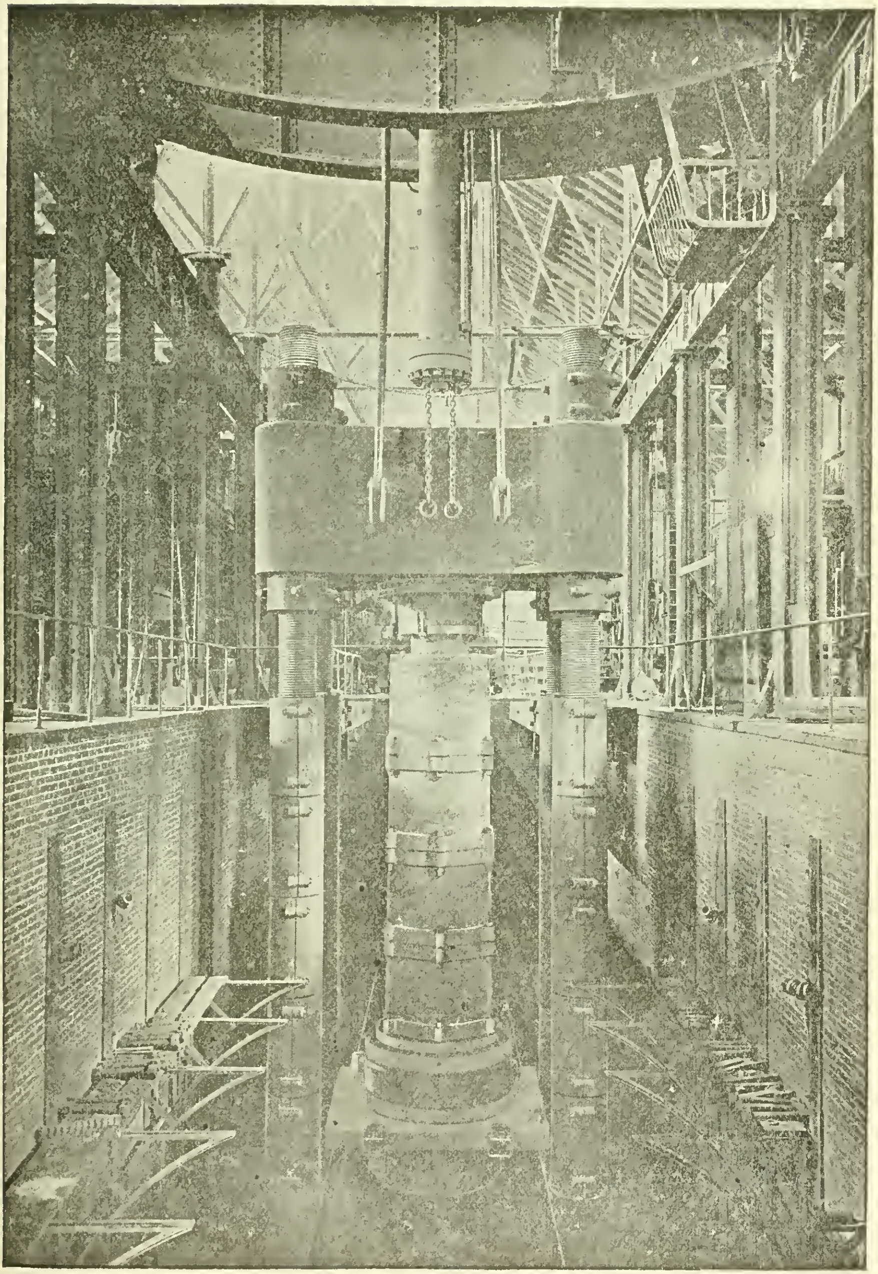


Fig. 3.

ing place, and when the charge is ready the metal is poured from the furnaces into ladles, which in turn empty into moulds located in the casting pit underneath.

Fig. 3 shows an end view of this pit. Here is a mould in which steel is supposed to have been poured from the ladles shown in the previous picture. Moulds of this character are from two to six feet in diameter and are built up in sections to any desired height. In order to make a forging properly, the best practice requires that an ingot be cast about twice its diameter, in order that sufficient work may be put into the original casting during the forging process to give the metal strength and toughness. Besides this increase in diameter a certain amount is added to its length, for reasons which I will try to make apparent to you.

There are various defects which are inherent in steel castings. In the first place, when pouring metal into the mould, air is apt to be entrained and cause blow-holes. In the next place, at certain stages of the cooling process gas is generated and will cause blow-holes of itself. There are several ways of overcoming these defects, but without doubt the most efficient is what is known as the Whitworth process of "fluid compression." In this the mould is placed on a platen and slid underneath an hydraulic press. (Fig. 3.) This press has a capacity of 7,000 tons, and under this enormous pressure the air which has been entrained in the pouring is forced out through joints in the mould where vents have been left for that purpose, and the gases which are apt to form in the cooling of the mass are prevented from generating.

Another defect, which is apt to occur in an ingot is known technically as "piping." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould, and as the solid metal keeps cooling towards the center it shrinks and draws away from it. We have, if you can imagine such a thing, a pot with metal in it which is really not sufficient to fill it properly, but which is being drawn out in all directions to fill it. This shrinkage draws principally from the center and the top, these being the parts that solidify last. It is, therefore, to take care of this shrinkage that more metal is added to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this added part down through the center, and

thus we are enabled to keep the latter filled where otherwise we would have a cavity or "pipe."

Still another defect which is apt to occur in ingots, and especially in those of very large size, is what is known as "segregation." This is partly a mechanical and partly a chemical separation of the various ingredients of steel (sulphur, phosphorus manganese, silicon, etc.) each of which has its own temperature of cooling. As the mass cools the tendency of these ingredients is toward the central and upper portions, where it cools last, thus forming a central core of impurities. This does not occur to such a great extent in small

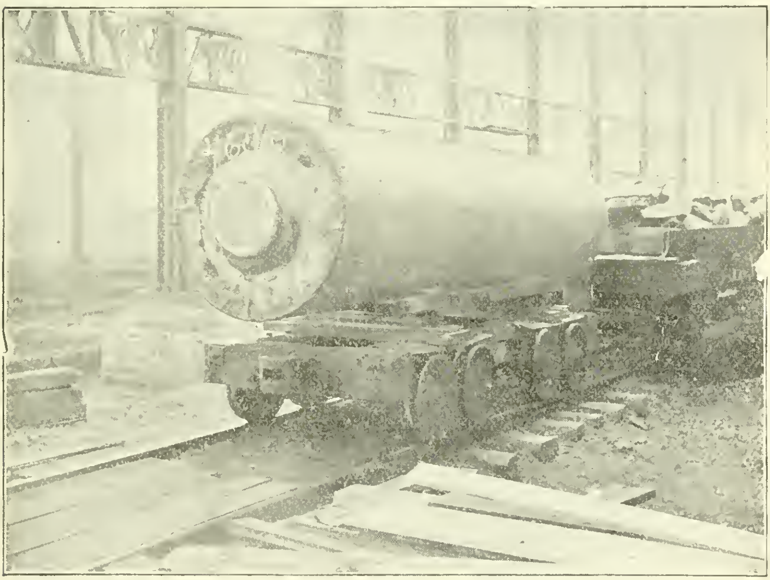


Fig. 4.

ingots, but in all large ingots it does occur, and even this process of fluid compression does not entirely prevent it. But it does succeed in giving us a perfectly solid piece of steel, with the exception of segregation in large ingots, and that defect, I will show later, can be taken care of. It is necessary that we should have an absolutely solid ingot at the beginning, because steel will not weld, and, if we have any defects in the ingot to start with, they cannot be remedied later by hammering, as might be the case if we were dealing with

iron, which, owing to the slag in its composition, as previously stated, possesses the property of welding.

Fig. 4 shows a fluid compressed steel ingot after being taken from the mould. It is twice the diameter of the forging to be made from it, and has considerable extra metal at its top to take care of piping and segregation, as already mentioned. This extra length, having served its purpose of supplying metal to fill blow-holes and pipes, and of collecting segregation, is cut off and returned to scrap, and the ingot is then ready for the forging process.

The first operation in the process of forging is the reheating of the ingot. This operation is a very delicate one, as great care must be taken to make the heat penetrate the metal slowly and uniformly.

As I have already told you, the metal in the ingot during the process of cooling is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain

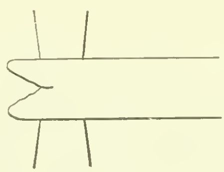


Fig. 5.

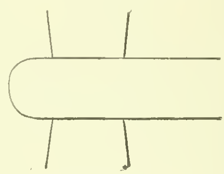


Fig. 6.

throughout its interior. Now, if we put a cold ingot into a furnace to be reheated, we immediately expand the surface metal and pull it still further from the center, thus putting an additional strain on the metal inside. In very large ingots cracks are thus apt to be started in the center, and forgings are very liable to break in subsequent service from the fact that they have not been properly reheated. This process is not considered of sufficient importance by forges generally, and a great many forgings fail from lack of care being taken at this time.

Now comes the forging process proper, and one of the first requisites is the proper selection of forging tools. The pressure applied in shaping a piece of steel should be of sufficient power and of such a character as to penetrate to the center and cause flowing throughout the mass. This flowing of the metal requires a certain amount of time, and the requisite pressure should be maintained throughout a corresponding period.

Fig. 5 shows the effect of forging a large shaft under a light hammer. The blow is made very quickly, forced by top steam, so that the metal has not sufficient time to flow and all that has been accomplished is damage to the surface metal without any effect whatever being produced on the center. There is a tendency to draw the surface metal away from the center, and on all large shafts which have been forged under light hammers will be found

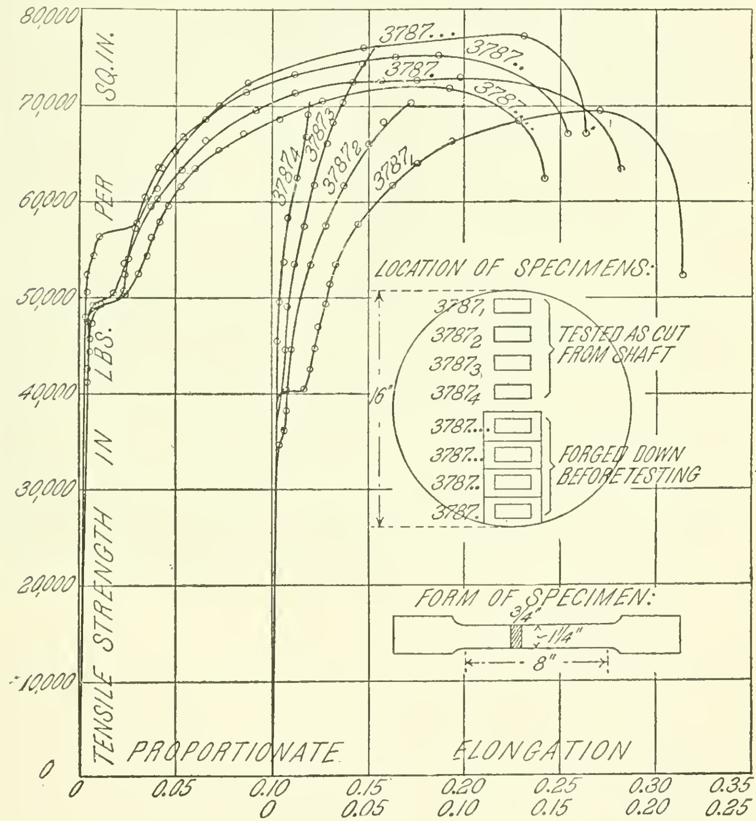


Fig. 7.

that well known concave end which is shown in the sketch, where the surface metal has been drawn away to such an extent as to leave cracks and sometimes large cavities in the center. What is shown at the end is simply an evidence of what has occurred all the way

through the shaft. Now, if we use a press in place of a hammer on a shaft of the same size, the pressure is applied very slowly, allowing time for the molecules of the metal to flow easily, and we then have the pressure passing all the way through the metal, and, as the center is hotter than the surface, and therefore softer, it will be squeezed out, and you will have the convex shape shown in Fig. 6 on the end of the shafts that have been hydraulically forged. By the press only can large shafts be obtained without defects formed during the process of forging.

Many so-called "steel forgings" are, even at the present day, turned out by forges which have not sufficient capacity to make them properly. Instead of working them down from ingots twice their diameter, as best practice dictates, they are compelled, because they have not hammers heavy enough to do the work, to use ingots which are only slightly in excess of the size of the finished forging. Such forgings are little better than steel castings and do not last long in service, and even when an ingot of proper size is insisted upon the surface metal only is affected, the center remaining in its original condition.

Fig. 7 is a diagram by Prof. Johnson, of St. Louis, showing a series of tests made at the Watertown Arsenal by the Government on a 16-inch shaft. This shaft was made for the United States cruiser "Dolphin" under a 10-ton hammer from a 30-inch steel ingot—which was very nearly the proper size—but broke after being in service a short time. In order to find out the cause of the break, test specimens were taken out of the metal at various distances between the surface and the center, specimens 3787_{1}—$_{2}$—$_{3}$ and $_{4}$ being taken first. Their form is given, and the tests are graphically shown in the curves. The test piece 3787_1, nearest the surface, showed an elongation of 21.4 per cent, and a contraction of 32.8 per cent; 3787_2 showed an elongation of 7.2 per cent and a contraction of of 5.5 per cent; 3787_3 showed an elongation of 4.9 (practically 5) per cent and a contraction of 5.2 per cent; and the one nearest the center showed an elongation of 2 per cent and a contraction of 1 per cent. In other words, the elongation varied, between the surface and the center, from 21.5 per cent to 2 per cent, and the contraction varied from 33 per cent to 1 per cent. You can see, therefore, that the center metal in this forging was practically unworked. In order to be certain that there was nothing in

the metal itself that would give this difference, they cut out from the opposite side specimens of a larger size and forged them down until they were of the same size as the first, or, to state it differently, they put work into the metal that ought to have been put into it when it was first forged, and, as a result, an average of 25 per cent elongation and 55 per cent contraction was obtained.

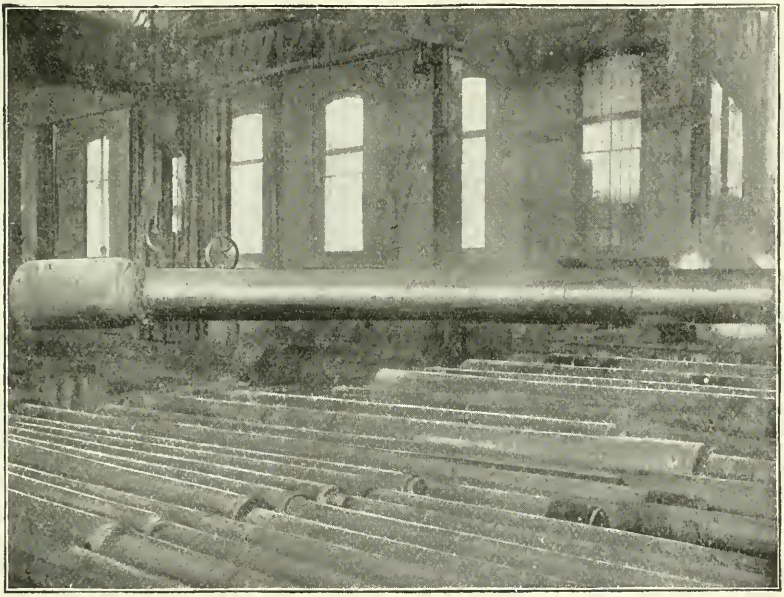


Fig. 8.

Fig. 8 represents the same ingot shown in Fig. 4, now being drawn out in the forging process. In this process of reduction in diameter and increase in length a great deal of work has been put into the metal. In order that the metal should be worked at the proper temperature, it is necessary to re-heat it a number of times, and every time a blow is made by the press the metal has been worked under conditions differing from those existing when the preceding blow was made, because it has cooled a little in the interval. As, therefore, no two parts of the forging when finished have been treated the same, it is natural to suppose that it is full of forging strains. It is also apt to have cooling strains in it, due to the fact that it has been re-heated from time to time in different

parts, as the forging process passes from one end of the piece to the other. To relieve these various strains all forgings are subjected to a final process called "annealing." This consists in put-

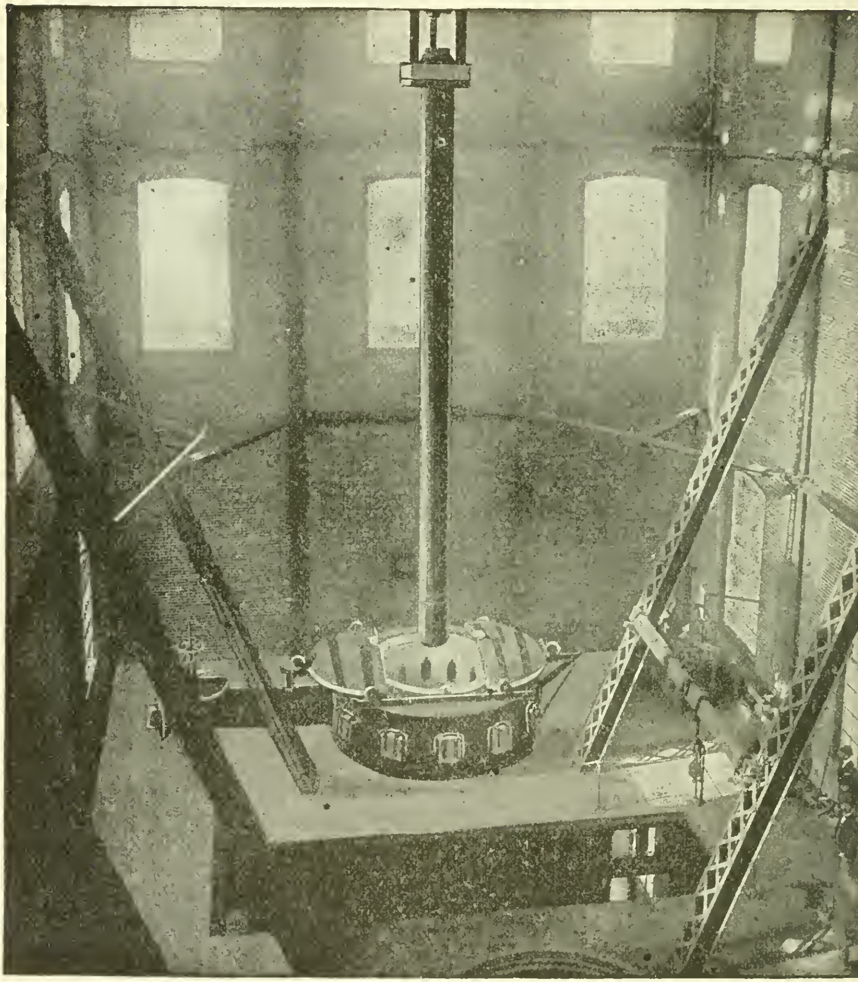


Fig. 9.

ting the forging into a furnace, starting a wood fire around it, and heating it to a definite temperature which experience teaches is best suited to the service to which the forging will eventually be

put; the fire is then allowed to die out and the furnace and forging to cool down slowly together. An annealed forging has its elastic limit somewhat reduced as compared to its tensile strength, but its ductility is increased considerably, as shown by its contraction and elongation in test pieces. The elastic limit of an annealed forging is invariably less than one-half of the tensile strength. By "elastic limit" I do not refer to the point usually determined by the drop of the beam in an ordinary testing machine, but rather to the carefully defined point obtained by more accurately determined methods, which is from two to ten thousand pounds lower.

All forgings should be annealed, and all specifications should be drawn so as to require that treatment. It is a process which is very seldom practiced in forges because not often required in specifications, and no one can tell whether a forging is annealed or not until after it has been in service for some time, when the cooling and forging strains develop and throw the piece out of shape.

In order to obtain from steel the very highest results there are still other processes to which it should be subjected after forging so as to develop its physical properties. One of these is that of "tempering."

Fig. 9 shows a tempering-plant. The forging is first re-heated to a definite temperature in a vertical gas furnace, then taken out and lowered suddenly into a bath of cold liquid, which may be oil or any other suitable fluid. The shaft in the picture is shown hanging from a traveling crane after having been withdrawn from the furnace, and is about to be lowered into the cold bath shown in the foreground. The forging must be subsequently annealed, as before, to relieve it of cooling strains. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition existing after forging is broken up, and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionately to the tensile strength, and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area in test pieces.

In order to successfully temper a piece of steel, great care must be taken both in the process of re-heating it and also in cooling it in

the bath. During re-heating the surface metal is apt to expand away from the center and thus cause cracks in the latter, as previously explained ; and in dropping it into the cold bath the surface metal is apt to contract on to the center to such an extent as to cause cracks in the former. In order, therefore, to successfully temper a forging it should be hollow. By taking out the centre, the piece can be re-heated without danger of cracking, because the center metal is absent and the heat gets into the interior and expands both it and the exterior together. Again, when immersing it in the cold bath, there being no solid center on which the surface metal is contracted, the danger of cracking the surface during the cooling process is in that way eliminated.

There are two ways of making a forging hollow. The ordinary way of getting rid of the center is simply to bore it out. After boring the forging is tempered, and thus the strength lost with the metal taken from the center is restored.

The hollow shafts which were first introduced into this country by Fried. Krupp of Germany have all been forged solid, bored, and oil-tempered. The high grade of that kind of work is well known.

Another way of getting rid of the center of large forgings is to *forge them hollow*. Any one who has not considered the subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. I have already explained to you that there are various defects which occur in ingots, the most serious of which are segregation and piping, and that it is in the center and upper portion where those defects occur. Now, if we were to cast a hollow ingot, replacing the center metal by a solid core of fire-brick or similar material, we would have two cooling surfaces, one on the outside and one around the core, and would transfer the position of last cooling to an annular ring midway between these surfaces, where we would collect the piping and segregation. This would not do, because the metal there is what we are going to depend upon for the strength of our hollow forging, and we are therefore compelled to make our forging solid, as before, so as to collect the piping and segregation in the center and at the top, where we have added metal to the original ingot for the purpose.

Then, having cut off the top and thus gotten rid of what piping and segregation are there, we bore out the center, and so eliminate the piping and segregation at that point, what we have left being as

sound and homogeneous a piece of steel as can be obtained (Fig. 10.)

After the hole has been bored, the next step is to reheat the ingot, and, since the center is taken out, as before explained, this process is not as delicate a one as if the ingot were solid. The heat affects the interior equally with the exterior and the two expand together, thus avoiding the danger of cracking. When the ingot is reheated we put a steel mandrel through its hollow centre, and, subjecting the two to hydraulic pressure, force the metal down and out over

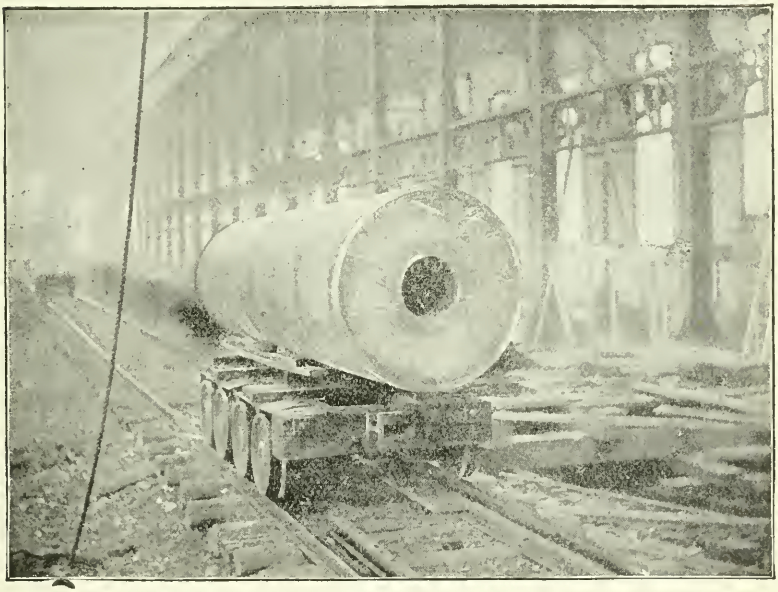


Fig. 10.

the mandrel (Fig 11). We thus practically insert into the forging an internal anvil and have therefore actually much less than one-half the amount of metal to work on that we would have had if the piece were solid. We have, for instance, in Fig. 12, a shaft 32 inches outside diameter with a 16-inch hole through it, leaving only 8 inches of metal to be worked upon between the press and the internal anvil.

A large number of hollow shafts of this type have been made for pumping engines in municipal and mining plants throughout the country, and similar shafts have also been made for engines in street

and elevated railway power-plants. These shafts have been about 28 inches outside diameter, 11 inches inside diameter, and twenty-five feet long. The Government requires that shafts for the navy shall be hollow, and this custom is being rapidly taken up in general marine practice.

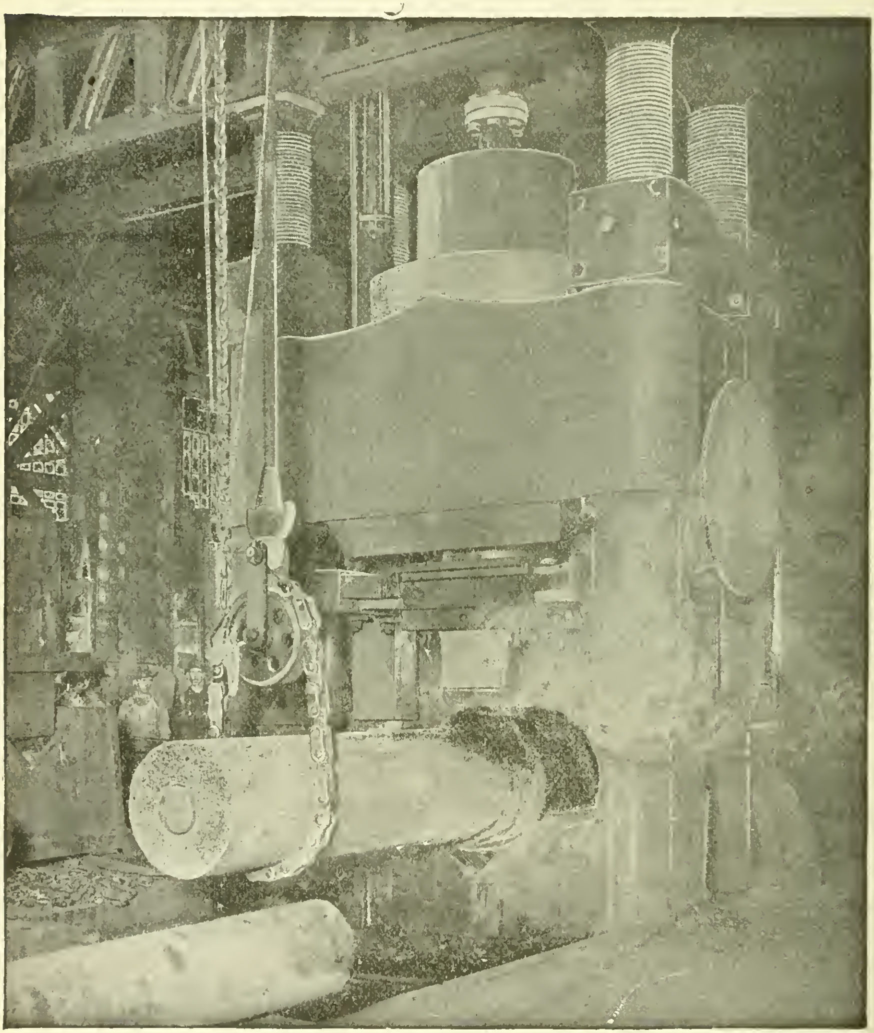


Fig. 11.

With the substitution in the trades of steel for wrought iron for engine and miscellaneous forgings, the tendency at first was to use a very mild, soft steel, approaching wrought iron in the ease with which it could be handled in the shop, especially in machining.

Mild steel, when of good quality, is superior to wrought iron in strength, toughness, homogeneity and freedom from danger of imperfect welds and porous spots enclosing slag, etc. Still it does not possess the very desirable quality of high elastic strength, combined with ductility or toughness, in as great a degree as can be obtained

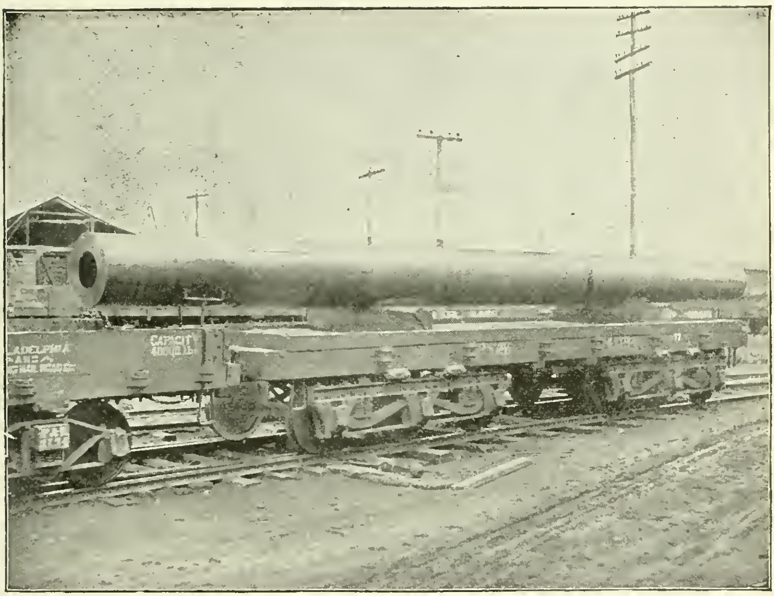


FIG. 12.

without danger in a harder steel, when proper precautions are taken in its manufacture.

It is only in recent years that high carbon steel has been found available for forging work. Fried. Krupp of Essen, Germany, was the leader in substituting his soft crucible steel for wrought iron, in heavy forgings. After 1870, soft open hearth steel became a more frequent substitute, with such success that, compared with wrought iron, the soft steel forgings made by well known English manufacturers soon attained a high reputation for their quality. It

was therefore natural that our government officials, when first issuing specifications for the heavy engine and shafting forgings required for the rebuilding of our navy, followed in the direction of the English practice, and called for a steel having a tensile strength of about 65,000 pounds per square inch, and a minimum elongation of about 28 per cent in four diameters. Today, however, we are called upon by our government to furnish a steel for the above purposes which will show a tensile strength of 80,000 pounds per square inch, an elastic limit of 50,000 pounds, and an average elongation of 25 per cent in four diameters.

The character of steel now used for crank-pins by many railroads furnishes a marked illustration of the practicability of using high carbon steels. When steel was first used in such pins, in place of wrought iron, a soft, low carbon steel was generally employed, and the failures due to "fatigue of metal" were almost as numerous as when wrought iron was used. The broken pins showed what has been called a "fracture in detail," a gradual parting of the steel extending inward all around the piece, undoubtedly produced by the working strains repeatedly approaching the low elastic limit of the soft steel. On substituting a steel with an elastic limit of 45,000 to 50,000 pounds per square inch, failures were greatly diminished without changing the diameter or shape of the pins.

"Fatigue tests" are made at the Watertown Arsenal by rotating rapidly a bar weighted in the center sufficiently to place the extreme fibres of the metal alternately in extension and compression.

These show the relative strength of steels of varying carbon to be about as follows :

.24 per cent	carbon steel,	annealed	229,300	rev.
.24	"	oil-tempered	348,000	"
.46	"	annealed	976,600	"
.46	"	oil-tempered	1,657,500	"
.66	"	annealed	3,689,000	"
.66	"	oil-tempered	4,223,600	"

The elastic limit, not the ultimate strength, is the proper point on which calculations should be made. This is the point which should not be exceeded at any time by the stresses which may be imposed upon metal. It is a point, however, very difficult to obtain

in ordinary practice, and requires delicate and special apparatus for its determination. It is usually considered to be the same as the "yield point" shown by the drop of the beam of the ordinary testing machine, but, when so determined, may be from 2,000 to 10,000 pounds too high.

This high carbon steel has been used largely by such representative pumping-engine builders as The Edward P. Allis Co., Fraser & Chalmers, H. R. Worthington, The Southwark Foundry & Machine Co., The Lake Erie Engineering Co., Holly Mfg. Co., E. D. Leavitt and others. In general it can be stated that experience now shows that, where high duty is demanded of a forging, mild steel of a tensile strength of 60,000 pounds is not the best material to use, owing to its low elastic limit. The tendency is now toward the adoption of a higher carbon steel, followed by such treatment as will raise the elastic limit relatively to the ultimate strength.

Engine builders, although fully alive to the advantages of the use of high carbon steel, are deterred from its use by the fact that it is very tough, and therefore the cost of machining in the shops is high. In competition with his fellows the engine builder who uses the lower carbon steel can bid lower than he who uses the better grade. It is therefore to the interest of the water works engineer, who specifies what he wants, to insist upon his specifications being worded properly, so that all the bidders can base their calculations on the same grade of material.

The water works engineer does not want his engines composed of a weak and unreliable material merely because the engine builder finds it easier and cheaper to manipulate in shaping. He should follow the progress in steel making and insist upon getting the best he can afford to buy. The first cost may be a little greater, but he will save by getting a material much stronger and stiffer, and which will receive a higher polish. The lessening of friction of such parts alone will pay the difference in cost by the saving in fuel and lubrication.

Experience must teach the engineer what quality of steel is best suited for the various parts of his engines, and his judgment must determine whether he will use a high quality and decrease the size of his forgings, or a cheaper grade, putting in more metal and taking greater risk.

Although forgings can be made to fill a large variety of specifications, they can in general be divided into six classes, as follows:

1st, mild steel, annealed.
2nd, medium hard steel, annealed.
3rd, " " oil-tempered.
4th, nickel steel, annealed.
5th, " " oil-tempered No. 1.
6th, " " " No. 2.

Each of these classes is supposed to cover a series of grades of steel, varying in strength by several thousand pounds. In selecting the material for the forgings of an engine, and in drawing up the specifications therefor, the premise should not be omitted that "all forgings shall be made of open hearth steel," and that "they shall be carefully annealed after forging."

Large shafts and similar forgings, crank and cross-head pins, should be made of fluid compressed steel, and should be hydraulically forged, not hammered. Wherever practicable, an axial hole should be bored through shafts to insure absence of any internal defects. If shafts are oil-tempered, the hole can be made larger in diameter than if they are simply annealed, and where the hole is 7 inches in diameter and above, shafts can be forged hollow on a mandrel. A hollow-forged, oil-tempered shaft insures the highest attainable qualities, and can be especially recommended where the maximum strength with the greatest lightness is desired.

Where it is important that the quality specified should be obtained in the more important parts, physical tests of the forgings as delivered should be demanded. For such tests prolongations should be left on the end of forgings for the purpose of having test specimens cut from them after the forging and subsequent heat treatment has been completed. Such prolongations should receive no greater reduction than the forging at its largest part.

The following table shows the average physical qualities that should be obtained in forgings made of the several grades of steel mentioned, the test specimens being 2 inches long between measuring-points, ½-inch in diameter, and cut from full size prolongations of the forgings after treatment; the elastic limit being determined not by the drop of the beam but by an electric micrometer.

Simple steel.	Tensile strength.	Elastic limit.	Extension percentage.	Contraction percentage.
1st, annealed,	58,000	28,000	28	55
2nd, "	80,000	37,000	23	45
3rd, oil-tempered, with axial hole,	80,000	45,000	25	50
Nickel Steel.				
4th, annealed,	80,000	45,000	23	45
5th, oil-tempered, with axial hole,	80,000	50,000	25	50
6th, oil-tempered, with axial hole,	90,000	60,000	22	50

Here are extracts from a few pump specifications picked up at random, from which it will be seen that they differ radically, although for about the same type of engine.

St. Louis Pumping-Engines. 1896.

"All steel forgings used in the construction shall be equal to forgings manufactured by The Bethlehem Iron Company, Bethlehem, Pa., and have a tensile strength of not less than 75,000 pounds per square inch of section, and show an elongation of 20 per cent in four diameters. Specimens to be taken from full sized forged prolongations after annealing. Shafts and crank-pins shall be hydraulic forged, fluid compressed steel. All steel forgings shall be properly annealed."

Chicago Pumping-Engines. 1896.

"All steel forgings used in shafts and crossheads shall have a tensile strength of not less than 65,000 pounds per square inch, and show an elongation of 25 per cent in 2 inches, and for connecting-rods a tensile strength of not less than 58,000 pounds per square inch, with an elongation of 28 per cent in 2 inches. Crank-pins shall have a tensile strength of not less than 75,000 pounds per square inch, with an elongation of 20 per cent in 2 inches. Specimens to be taken from full sized forged prolongations after annealing. All forgings shall be thoroughly annealed."

Boston Pumping-Engines. 1896.

"The crank-shaft and crank pins shall be of the best quality of forged fluid compressed steel.

"Steel forgings shall have a tensile strength of not less than 60,000 pounds per square inch of section, and show an elongation of not less than 20 per cent in 8 diameters. No steel shall be welded."

New Bedford Pumping-Engines. 1897.

"All forgings are to be of crucible or nickel steel; each piece to be oil-tempered. All steel is to have at least 50,000 pounds elastic limit per square inch, and 18 per cent elongation in 10 inches in test pieces 1 inch in diameter. Where forgings are shown to be bored out they may, if preferred by the contractor, be hollow forged instead of bored."

Buffalo Pumping-Engines. 1897.

Specifications read same as for the St. Louis pumping-engines above mentioned, and, in addition:

"The steel shall not contain more than .04 of 1 per cent of either sulphur or phosphorus, and not less than .40 of 1 per cent carbon."

Boston Pumping-Engines. 1897.

"The crank-shafts, cranks and crank pins, the piston, connecting, and plunger-rods, the crossheads and crosshead pins shall be made of fluid compressed or crucible steel of substantial proportions. Test pieces for forgings shall be cut from full size prolongations of forgings and shall receive the same treatment as forgings. Steel forgings for crank-shafts, cranks, crank-pins, crossheads, crosshead-pins, plunger, connecting, and piston-rods shall have an elastic limit of not less than 50,000 pounds per square inch and an elongation of not less than 18 per cent in 10 inches in a test piece 1 inch in diameter. Steel forgings shall be made without welds."

Chicago Pumping-Engines. 1897.

"All steel forgings used in the construction shall be equal to forgings manufactured by The Bethlehem Iron Co., Bethlehem, Pa., and have a tensile strength of not less than 65,000 pounds per square inch of section and show an elongation of 20 per cent in four diameters. Test specimens are to be taken from full sized forged prolongations after annealing. Shafts and crank-pins shall be hydraulic forged, fluid compressed steel. All steel forgings shall be thoroughly annealed."

Cincinnati Pumping-Engines. 1897.

"All steel must be of open hearth make, and shall contain not more than .05 of one per cent of phosphorus and not more than .03 of one per cent of sulphur. It shall be tough, ductile, of uniform texture and composition, and shall show a fracture of fine silky grain.

"Different grades of steel when tested in specimens of $\frac{1}{2}$ square inch in sectional area, cut out of the finished piece, shall give the following results:

"Tensile stress without breaking, not less than 70,000 and not more than 80,000 pounds.

"Elongation in twelve diameters 20 per cent.

"Cold bending of specimen 180 degrees and setting flat on itself without sign of fracture.

"All steel forgings shall be hydraulic forged and properly annealed."

Pumps for Pope Manufacturing Company. 1895.

"The shafts are to be of fluid compressed open hearth steel, oil-tempered when built up, and properly annealed when not built up, having an elastic limit of 45,000 pounds, and 18 per cent elongation in 10 inches, in a test piece of 1 inch diameter."

It has been customary in the past for cities to have water supplied at moderate pressure throughout their systems of mains, and, in case of fire, etc., special engines take their supply at hydrants in the immediate locality of the fire. Owing, however, to the great drain on the mains at certain hours of the day, some cities have laid special systems of fire-mains through their streets leading to some accessible water front, patrolling which are fire-boats equipped with powerful pumping-engines. These engines supply water to the special mains at very high pressure.

These boats must be of light draft, and, necessarily, the pumps must be very light and strong, and the highest grade of steel must be used in their construction.

Centrifugal pumps, turbines and similar apparatus, which work on either solid or hollow shafts, should be supplied with a grade of steel suited to their requirements.

The power plant at Niagara, which comes in the above category, has specified for it steel having an elastic limit of 55,000 pounds, elongation of 23 per cent and contraction of area 50 per cent. Fig. 13 shows a specimen forging made for that plant.

I trust that I have been able to gather together for the members of this Association a few suggestions regarding forgings which may result in a saving of time and labor in searching for such information elsewhere.

I have endeavored to point out the direction in which improvement in forging processes is tending, and to offer suggestions by which the various grades of steel forgings can be obtained. If I

have succeeded in satisfying you that the day of wrought iron forgings has passed, and that the use of mild steel forgings is rapidly giving way to steel of higher carbon, I will feel that I have accomplished what I started out to perform.

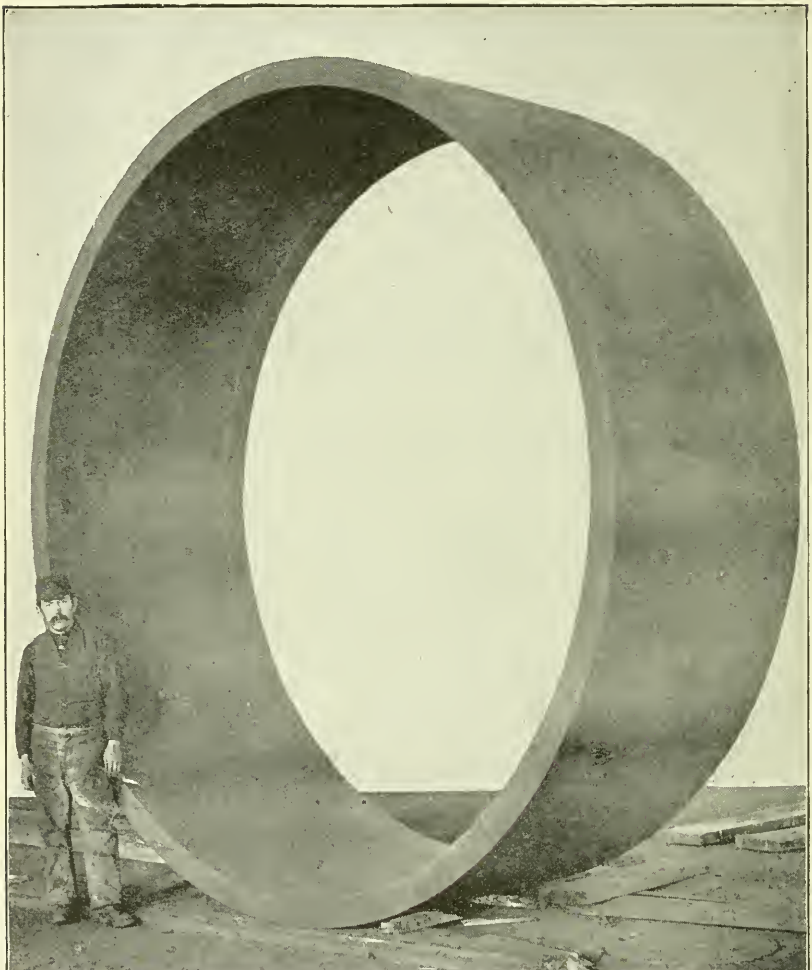


FIG 13,—Field ring for one of the 5000 H. P. Electric Generators at Niagara Falls. Outside Dia., 11 ft. $7\frac{3}{8}$ in ; width, 4 ft. $\frac{3}{4}$ in.; thickness, $5\frac{1}{4}$ in.

NOTE.—Papers on this and analogous subjects have appeared in the Transactions of the Society of Naval Architects and Marine Engineers, Vol. I, 1893, by R. W. Davenport, and in Proceedings of the Engineers' Club of Philadelphia, Vol. XIII, No. 4, by A. L. Colby ; also in Vol. XVII of the Transactions of the American Society of Mechanical Engineers by H. F. J. Porter.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XII. March, 1898. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

CONSTRUCTION OF THE NEWPORT, N. H., WATER WORKS.

BY LUCIAN A. TAYLOR, C. E., BOSTON, MASS.

[*Read Dec. 8, 1897.*]

Newport, N. H., is on the Concord & Claremont branch of the B. & M. Railroad, a few miles west of lake Sunapee. The great game preserve of the late Austin Corbin lies partly in the town.

The village contains a population of about 1,500 people, and is beautifully located in the valley of Sugar river, the outlet of lake Sunapee.

The water works were built in 1894.

Water was taken from Gilman's pond in East Unity, about six miles southwest from the village. This is a natural pond of very pure water, the shores being very clean and free from vegetable growth, and composed of sand and gravel. It has an area of 65¾ acres, and is said to have a depth of from 40 to 50 feet.

A dam was built at the outlet of the pond to replace a small one that had been used by mill owners on the stream below. The exact area of the water shed is not known but is believed to be about one square mile. The dam is 8 feet wide on top with inner and outer slopes 2 to 1. The greatest height is about 14 feet, length 126 feet, wasteway partly over natural rock, 34 feet in length. The inner slope is paved with field stone. A core wall 3½ feet thick at the bottom, 2 feet thick at the top, extends to within 1½ feet of the top of

the dam. Its greatest height is about 13 feet. It is laid in Rosendale cement mortar, the stones being ordinary field cobbles of rather small size, no stone allowed to lay more than two-thirds the width of the wall.

A 12-inch waste pipe extends through the base of the dam to a gate chamber 66 feet from the top slope of the embankment. The supply is through an 8-inch pipe laid parallel with the waste pipe, and terminating in the gate chamber.

The gate chamber is 10 feet square at the base and 8 feet square at the top outside. The walls are 3 feet thick at the bottom, and 2 feet at the top, laid of rubble masonry in Portland cement mortar, and are 12 feet high. The foundation is 3 feet thick, of rubble masonry, laid in Portland cement mortar.

A brick gate house was built over the gate chamber in which are the gate rods. On the up stream face of the gate chamber, there is an opening 2 feet in width extending from the top of the foundation to the floor of the gate house. On the sides of this opening are grooves formed by placing angle irons in the masonry. These are to hold the stop plank and screens.

The foot-bridge connecting the gate house with the dam is in two spans, each about 33 feet in length, supported at their connection by two cast iron columns made of 8-inch cast iron water pipe filled with cement concrete, and built into stone foundations in the bottom of the pond. The depth of water in the gate chamber is 8.4 feet, and the amount of water above that level is 166,000,000 gallons. Practically about 150,000,000 gallons can be drawn.

The elevation of Gilman's pond is about 480 feet above the lowest point of the village. The supply is through 1435 feet of 8-inch, and 23,771 feet of 6-inch pipe laid across private lands, and along the highway, to a reservoir about one mile from the centre of the village.

There are numerous abrupt summits along this pipe line. Eight or nine stops for air valves were placed along the line. They are made of $\frac{3}{4}$-inch stop and waste and $\frac{3}{4}$-inch upright pipes. A box is placed over each stop. After the first filling of the pipe line, these stops are rarely if ever used, even when a considerable portion of the water has been drawn off.

The elevation of the reservoir is 169 feet below Gilman's pond. The capacity of the pipe line is about 400,000 gallons per 24 hours.

The reservoir is built upon a steep side hill, the average slope of which is about 21 feet per 100. The capacity of the reservoir is 701,-300 gallons. The embankment on the lower side is 13 feet in width on top. The inner slope is 1½ to 1. The outer slope, about 2 to 1. The depth of water is 12 feet. The bottom of the reservoir and inner slope are paved with ledge stone 12 inches in thickness. The top of the embankment is 4 feet above high water in the reservoir. The reservoir at high water mark is 104.5 feet x 116 feet.

Three lines of pipe pass through the westerly or lower embankment; one is an 8-inch waste pipe, passing through the gate chamber and terminating just outside the wall. In the gate chamber there is an upright pipe acting as an overflow from the reservoir. The supply pipe from Gilman's pond 8 inches in diameter at this point, passes through the gate chamber to the centre of the reservoir, terminating in a quarter turn. The distribution main for the village, 12 inches in diameter, passes through the gate chamber, also terminating about 12 feet from the outside walls. Over the end of this pipe is a copper wire screen, 14 inches in diameter and about 15 inches in length.

At the upper or southeast corner of the reservoir, there is a wasteway over the natural ground placed at the same elevation as the overflow pipes in the gate chamber.

As the reservoir was made somewhat larger than at first contemplated, the additional excavation required, uncovered a portion of ledge in the northeast corner and also over a considerable portion of the bottom of the reservoir. In excavating this ledge which for the most part was smooth, solid granite, it was discovered there were holes and fissures of considerable depth and extent, extending across the bottom of the reservoir, and at the northwest corner, underneath the embankment already built. These crevices were followed, uncovered, and exposed, as far as possible, the loose fragments of rock in the crevices being taken out as far as practicable. The holes were then filled with pure cement grout, and allowed to set for several days. The surface was then covered with from 18 inches to 3 feet in depth of well rammed and puddled material from the excavation of the easterly slope of the reservoir. This material was of excellent quality, having sufficient amount of clay to make it water-tight. The reservoir embankment is entirely of material from the excavation, no masonry or core wall being used in

its construction. Trenches were excavated in the natural ground $3\frac{1}{2}$ feet in width, and $3\frac{1}{2}$ feet in depth into the impervious material, and filled with puddle from the excavation. They extended the entire length of the lower or westerly embankment, and somewhat more than past the centre of the reservoir on the northerly and southerly ends. Masonry was placed around the inlet pipes through the embankment to the gate chamber. There are also several cut-off walls extending below, above and upon each side of the pipe wall.

It may be of some interest to note the result of this method of dealing with the fissures uncovered in the rock excavation. The reservoir has now been in use three years, and is in a perfectly good condition. There was some percolation when the reservoir was first filled, mainly showing itself in the increased flow of a spring about 200 feet distant from the southwest corner of the reservoir. This flow has considerably decreased since the reservoir has been in use. The amount of actual percolation from the reservoir itself is difficult to estimate, as the spring was a very constant and powerful one during the entire construction of the work. It is probable the percolation amounts to from 15,000 to 20,000 gallons in 24 hours.

In the northwest corner of the reservoir a considerable portion of the rock is left exposed, forming the inner slope of the basin. The writer has no doubt that most of the percolation finds its way through minute crevices and seams in this rock, and not through the bottom or lower embankment where the cement grout and puddle had been placed in and over the crevices.

There were used 56 barrels of cement in filling these holes, which extended in some cases, 20 or 30 feet in length, and from 1 to 12 inches in width. These fissures were, no doubt, occasioned by the movement down hill of the entire slope which rises several hundred feet above the location of the reservoir. These holes and crevices also account for the large and constant flow of the spring, which during time of construction supplied at all times an abundance of water for use in the construction of the embankment and masonry, and also for the men and teams employed upon the work.

It is not probable that any movement of the slope of the hill is taking place at the present time, or is likely to take place in the future, although such things do occur frequently in granite and other quarries in New England.

The distribution system is through 976 feet of 12-inch, 4826 feet of 10-inch, 4985 feet of 8-inch, 16,583 feet of 6-inch and 1926 feet of 4-inch pipe, a total of 29,296 feet, or 5.55 miles, upon which are placed 50 hydrants and 49 gates.

The pressure upon the mains ranges from 90 to 134 lbs. per sq. inch. Near the foot of the hill below the reservoir, and at the lower end of the 12-inch pipe, there is a connection with the supply pipe from Gilman's pond, so the village may be supplied without the water passing through the reservoir. The entire length of the pipe line as laid is 55,075 feet or 10.43 miles.

Work was begun on this system June 11, and completed Nov. 15th, 1894, since which time the works have been in constant and regular use.

At a test of the system when the reservoir was partly filled with water, 9 fire streams were used with a reduction of about 20 lbs. in pressure upon the street mains.

More streams were not used for lack of hose and nozzles. About one year ago a connection was made with a large woolen mill and upon a test, 11 good fire streams were thrown from the dead end of an eight-inch main, about 1½ miles from the reservoir.

DISCUSSION.

Mr. Haskell. I would like to ask Mr. Taylor if the character of the water has been good ever since they commenced using it?

Mr Taylor. It has been uniformly good. The dam I spoke of did not raise the water above its natural flow line. There had been a dam built by mill owners so that they might draw 7 or 8 feet, but that was mostly of natural soil, and I simply replaced the old structure with something more substantial, but without raising the water above its natural level; it simply enabled us to draw 8 feet off from the natural elevation.

Mr. Fuller. I didn't exactly understand Mr. Taylor when he spoke about this "movement," whether it was before the reservoir was constructed?

Mr. Taylor. I suppose that was in prehistoric times; a geological movement. I have seen in granite quarries those movements, which would be visible in a few hours, not visible to the eye, but sometimes when a steam drill gets stuck or something of that kind, there is a movement in a quarry where there are very steep

slopes. My statement about that was that it seemed to me this thing might have occurred thousands of years ago, as the rock in most places is covered with from 4 to 10 feet of earth.

Mr. Holden. I would like to inquire whether any air forms around the air-valves at any time when the water is drawn from the pipes. Do you have to open these valves every time it is drawn off?

Mr. Taylor. Very rarely. There are one or two summits which occasionally give a little trouble, but usually the velocity through the pipes is so great, it pulls the air along with it. I think that is the solution of it, because there is a considerable amount of air which has to go, and I think it is mixed with the water as it passes on its way to the reservoir or to the village. The first filling of the pipe line took a good deal more time than we anticipated, because in addition to the eight or nine summits which were treated by these small blow-off pipes, there were other minor summits, and those in the first filling of the pipe also tended to retard the flow of water very materially; but since the first filling they have given no trouble. And I think very often, when there is an accumulation of air in the pipes, it is carried along with the water from the fact of its being under considerable velocity.

Mr. Walker. Did you clean out this reservoir or old mill dam, before you let the water in?

Mr. Taylor. Yes, but there was very little of it. Probably the whole contents of the dam didn't amount to more than 50 cubic yards or 100 cubic yards, so it was a very small matter.

Mr. Walker. Mr. Cook in his paper at Newport spoke about filling a new reservoir on natural ground, and he said there hadn't been any bad effects from it. Now on the Metropolitan system where they are going to fill a large reservoir, they intend to take out all the loam, which is quite an expense. It is a question in my mind whether they could not let a certain portion of it remain, but they say they intend to take it all off, where there is more than three inches. For instance, on the sides there is loam two or three inches on a sandbank, and they are going to take that off. Now Mr. Cook said he didn't have any bad effects from flowing a reservoir on the natural ground, without taking off the loam; and I would like to know if anybody else has had such an experience as that. It means the saving of a good deal of expense in the case of an in-

tervale, where there are no bushes or anything of the kind, if you don't take the loam off.

Mr. Taylor. I suppose it comes to this, that the vegetable matter taken from the reservoir is so much poor material out of the way. In the case of the reservoirs at Worcester which have been in use a great many years, they have but very little trouble. At the same time those reservoirs are being somewhat improved, and that probably will do away largely with whatever slight trouble there may have been at times.

Mr. Cook. The matter referred to by Mr. Walker is the construction of the new No. 3 reservoir of the Woonsocket Water Works. The dam was built and then came the question whether the reservoir should be cleaned or not, and as that would involve a large expense which the city could not afford, the material was left in it; and we haven't experienced any trouble either from the taste or the smell of the water which has been used from the new reservoir. The first season it was filled there was a slight scum formed in the shallow portions on the back side of the reservoir from the dam, and this season we didn't observe any at all. But I presume that that reservoir, situated as it is and used as it is, furnishes an unusually favorable condition for not showing any bad effects, because the water runs about two miles and a half to the pumping station, where the water is taken by the pump, and drops about 165 feet on the way, which aerates it, and probably any trouble there may be with the water when it leaves the new reservoir is gotten rid of in its passage through the open brook.

Mr. Coffin. I would like to ask if that is mixed with the water at the pumping station?

Mr. Cook. Yes, it runs into the water at the pumping station.

Mr. Coffin. Does that make any difference in the quality of the water?

Mr. Cook. No, because the reservoir at the pumping station is so small, I don't think it makes any difference.

Mr. Fuller. I think something was said at that meeting at which Mr. Cook read his paper in regard to the possibility, or the feasibility of taking some of the money which it would cost to clean out this reservoir and use it to construct filters.

Mr. Cook. That matter was looked into, and the expense of putting in a mechanical filter was estimated at about half the cost

of cleaning out the reservoir. But mechanical filtration being in the state it is now, there has been no attempt made to filter the water, especially as we have had no trouble otherwise than that the color is high. I cannot give you just the rate as compared with the Massachusetts reports, but I should think it is somewhere from about 70 to 75.

Mr. Metcalf. I would like to ask Mr. Taylor what sort of a regulating device, if any, was used for admitting the water into the reservoir from the upper pipe line?

Mr. Taylor. None whatever. The mains were entirely independent, that is to say, there was a direct pipe line from Gilman's pond to the distributing reservoir. There also was a connection between the distributing main and this main from Gilman's pond, and I think it actually is used directly from Gilman's pond, the upper reservoir. There is a somewhat amusing circumstance connected with that connection between the two pipe lines. Gilman's pond having, as I think, something like 408 feet head, I told them it was just as well to leave the gates open between the two lines. They couldn't quite understand why they wouldn't get the full head of water from Gilman's pond. I explained that the reservoir would act as a regulator for that. But some men selling supplies of various kinds almost convinced some of the commissioners that I must be wrong. At any rate, when I wasn't there, they thought they would open the connection between the two pipe lines and watch the result, having a man stationed to open a large blow-off on Main street in case the pressure gauge went up to an excessive height, and this was done. The gate was opened, but of course nothing happened, and so they concluded that they were all right. But there are the two pipe lines, and there are no regulating devices whatever on them. The superintendent wrote me only a few days ago that they did keep one of the main gates on the supply from Gilman's pond partly closed, simply because there was more flow of water through the pipe line than they wanted. There is almost always a certain amount of waste, and they wish to keep that waste down to the minimum. That is to say, the capacity of the pipe line is something over 400,000 gallons a day, and they are using only possibly half that, without any regulating device.

THE WORCESTER DISTRIBUTING RESERVOIR.

BY WALTER E. HASSAM, C. E., ASSISTANT TO THE CITY ENGINEER.

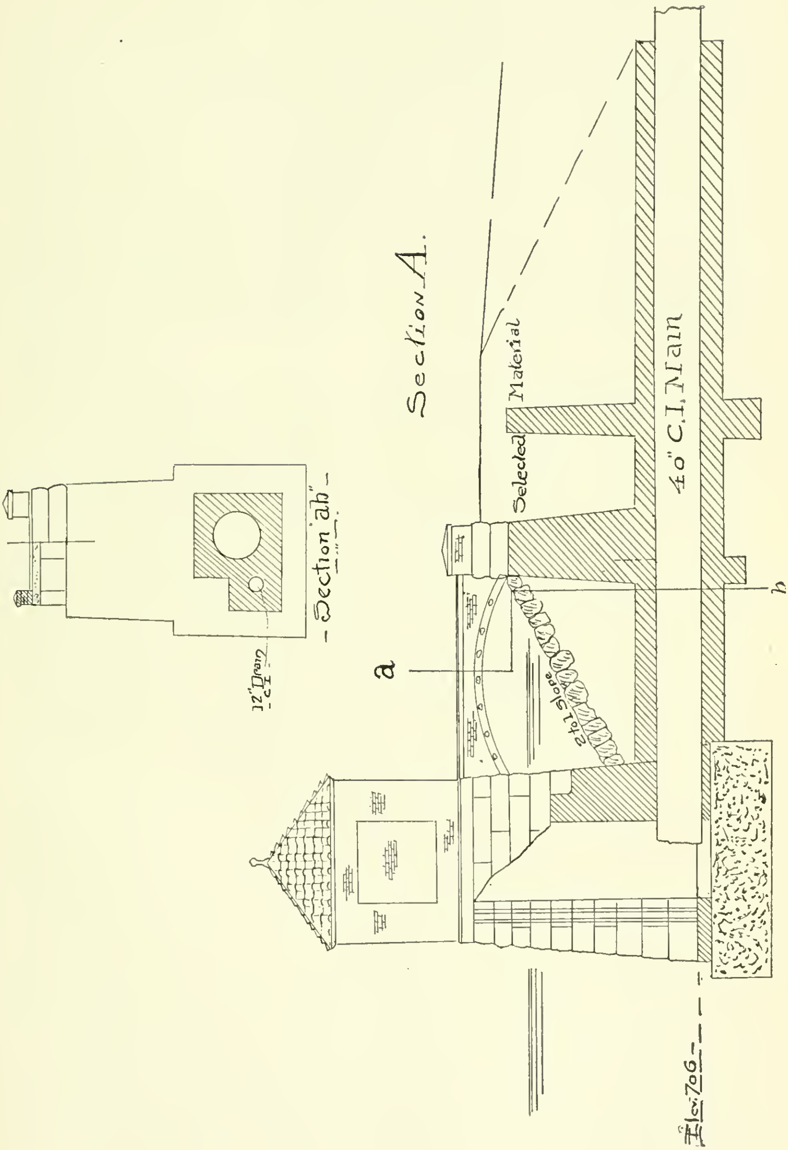
[*Read Jan. 12, 1898.*]

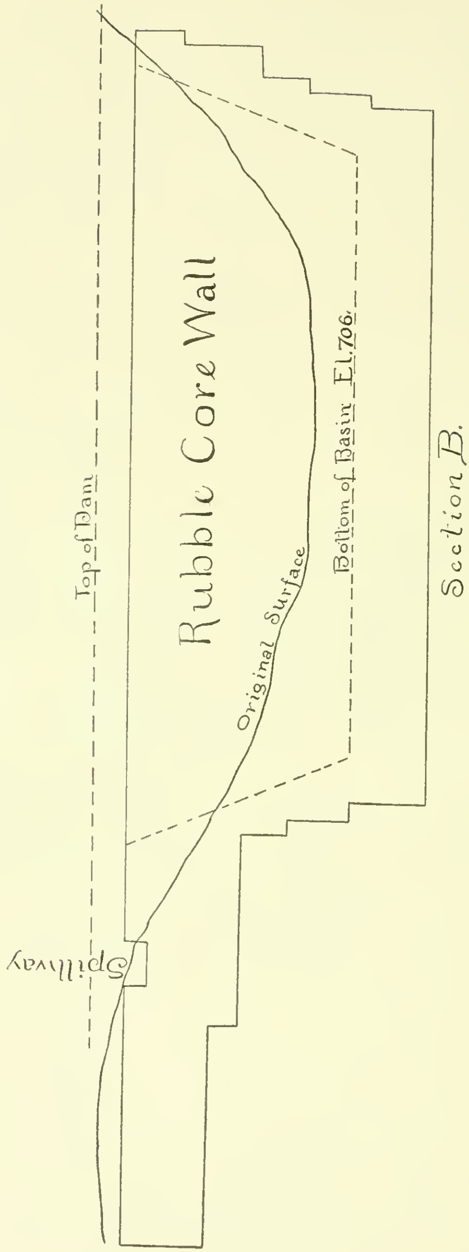
In the years 1893–4, it was apparent to the city engineer and some other officials connected with the water department of Worcester, that something must be done for a future supply of water for the fast growing city of Worcester, and it was decided that Kettle brook, flowing through the towns of Paxton and Leicester, with several large reservoirs situated thereon, and about 2300 acres water shed, was the best source of supply that could be attained. So the city secured the right to take Kettle brook above what is known as the Kent's Mill privilege, including all reservoirs above said privilege, ten rods around all reservoirs, and 50 feet each side of the brook. Several surveys were made, and it was found that near the Kent's mills with little expense, Kettle brook could be diverted into Lynde brook reservoir, the city's high service reservoir. The old dam at Kent's not being considered suitable necessitated a new one, and a new earth dam with rubble cement core wall was built, and the water diverted through a 30-inch pipe. As a great deal of this water is needed on the low service system, a cut was made in the Lynde brook reservoir to the depth of 26 feet, and a 30-inch pipe, encased in rubble wall, with two cut-off walls on the up stream side of the core wall was put in and a gate house of New Hampshire granite was also built. In making the cut in the dam the embankment was opened 12 feet wide and carried to a depth of 18 feet. The sheeting was cut three feet long and put in and well braced as the work progressed. At the depth of 18 feet two steps were made on the inside of two feet, and the cut continued in the same manner to the required depth, the last eight feet in depth being the same width as the wall around the pipe, and the wall was built against the banks with no side filling. After the pipes and walls had been laid the filling was spread in

2-inch layers and hand tamped, the sheeting being taken out three feet at a time, commencing from the bottom. The 30-inch pipe was continued down the valley about 4600 feet to the Parson's brook reservoir, which was under construction.

Parson's brook reservoir was built for distributing purposes only, having an area of 2.5 acres and capacity of 8,392,574 gallons, and 104.82 feet lower than Lynde brook reservoir, which elevation corresponds with the elevation of the proposed dam in Holden, on the low service system. Until this reservoir is built the pressure is equalized with the Holden supply, which is somewhat lower, with three 16-inch Ross regulating valves.

In making the surveys for the Parson's brook dam it was found that nature had done a great deal for us, for the exact elevation wanted was a suitable hollow surrounded on three sides by small hills, plenty of stone for core walls, and good material with sufficient clay in it to pack well for embankment. As Parson's brook flows through a boggy swamp and has only about two hundred acres water shed, it was not considered worth what it would cost to take it. So the course of Parson's brook was changed and carried around the reservoir on the west side by building a dyke. The earth on the site of the dam was excavated to a good foundation, which averaged 4 feet to 12 feet below the bottom of the basin. The trench for the core wall was carried somewhat lower, as shown by section "B." The basin was excavated to the elevation of 706 feet, and the slopes made two horizontal to one vertical, paved 1½ feet thick, 2 feet above and 4 feet below high water mark. This work was carried on at the same time as the construction of the dam. Thirty-six thousand cubic yards of material was taken out of the basin, which contained stone enough for the paving and core wall, also good material for the embankment. Section "A" shows the embankment 13 feet wide on the top, the up stream slope 2 feet horizontal to 1 foot vertical, the whole slope being paved the same as the sides of the basin. The down stream side was graded back with waste material from the basin 200 feet straight grade. The depth of the water in front of the dam averages 13 feet, the top of the dam 3½ feet above the spillway. The essential feature of the new work was the building of an earthen embankment, through which was a rubble wall. This wall is nearly in the centre of the embankment and was carried well into the east bank and into the


Section A.
Selected Material
40" C.I. Main
Section "ab"
12" Drain C.I.
2 to 1 Slope
a
b
Elev. 706


Top of Dam
Rubble Core Wall
Original Surface
Bottom of Basin El. 706.
Section B.
Spillway

natural bank of the dyke on the west side, and built in the following manner: The stones were hauled on boats, washed free from dirt, and laid in the wall with plenty of Rosendale cement, well mixed, two parts sand and one of cement, great care being taken that no stone reached through the wall, which is 3 feet wide on the bottom and 2 feet wide on top. When the wall was brought to the height of about 5 feet above the foundation for the dam the embankment was started by spreading layers of clay material four inches deep, moistened (not wet) and rolled with a 3-ton grooved roller, the earth around the walls being well tamped with hand tampers. When the embankment was within 18 inches of the top of the wall, the wall was continued, then the embankment, and so on to the top.

The 40-inch main pipe and a 12-inch drain pipe through the dam are encased in rubble wall 6½ by 9 feet, with one cut-off wall of about 8 feet from the core wall on the up stream side. The cut-off wall protrudes 2 feet on the bottom and on both sides, the top being carried up to the top of the dam and acting as an abutment for bridge to gate house. The gate house is built on a concrete foundation, the sub-structure of New Hampshire granite, the structure of straw colored brick with marble trimmings, and the roof of copper. The bridge from the crest of the dam to the gate house is an arch concrete, with brick same as gate house for parapets and marble coping. Two posts at the end of the dam are built of granite, brick and marble cap. The floors of the gate house and bridge are concrete with smooth surface. In digging for the foundations of the gate house a pocket of quick sand was found with plenty of water. A well was sunk 6 feet square about 15 feet from the foundation in the direction the water was coming from, and the vein cut off. By keeping this well pumped, work could be continued on the foundation. The well for the gate house was pile sheeted with tongued and grooved plank, sunk 6 feet below the bottom of the reservoir and filled up with concrete, using Portland cement, the sheeting being left in. The other well was walled up in cement, 18 inches square, and the water left to rise as high as it would, then it was pumped out and filled with concrete, clay being tamped on the outside of the wall. In digging for the foundation of the dam on the west end another spring was found which was treated in the same way.

The spillway is 13 feet wide and empties into the canal or new course of the brook. The wing walls are New Hampshire granite. The wier stone crosses on top of the core wall and tongued into the wing walls. Both slopes are paved with street block paving and grouted with Portland cement. A gate was placed 24 feet from the entrance of the 30-inch supply pipe to the basin, and just back of the gate a 4-inch connection was made and the pipe taken under ground to the center of the reservoir, where a stand pipe was erected for a fountain; this adds a good bit to the beauty of the reservoir. The stand pipe is encased in a cement wall six feet square on the bottom and 4 feet on top to protect it from the ice. A road was built from the main road below the new dam to the main road below Lynde brook reservoir, a distance of about one mile, it crosses the stream just below the new dam, follows the east shore of the basin and crosses again just above the basin, thence over pipe line to Lynde brook reservoir. Two small rustic bridges 16 feet long and 8 feet arch were built where it crosses the stream. The arch was built of field stone, laid in Portland cement. The parapets are made of selected cobble stone, the top of the parapet left ragged. This makes a very durable bridge and also pleasing to the eye. The water from this reservoir is measured by a Venturi meter connected with the 40-inch pipe, about fifty feet lower than Parson's brook reservoir.

DISCUSSION.

Mr. L. Taylor. I suppose the use from this reservoir is three or four million gallons per day?

Mr. Hassam. That is what they intended to use.

Mr. Allis. May I ask what the size of the watershed is which supplies that amount of water?

Mr. Hassam. At the present time the watershed which we can draw from through this 40-inch pipe is over 4300 acres.

Mr. L. Taylor. I would like to ask what that new gate-house in the enclosure of Hunt's reservoir is for?

Mr. Hassam. That is the house for the Venturi meter on the 40-inch main pipe.

Mr. Whitney. Have you made sufficient tests with this Venturi meter to determine its accuracy?

Mr. Hassam. I have not made any experiments or tests with

this Venturi meter, but I had supposed it was acknowledged by most engineers that these meters are almost absolutely correct. In Holden we have a large reservoir that holds in the vicinity of 740,-000,000 gallons of water, below that we have a small distributing reservoir, and just below that distributing reservoir is a Venturi meter, which we have tested in this way: We have put in a weir just above the small reservoir, and measured the water over the weir, and then measured it through the meter. We have found the two measurements to correspond. That is the only way we have ever, to my knowledge, tested the Venturi meter.

Mr. L. Taylor. I would like to have Mr. Hassam state, for it may be of interest to the association, the number and sizes of the Venturi meters in use on the Worcester water works.

Mr. Hassam. There are four in all; two on the 30-inch high service pipe, one on the 40-inch pipe, and one on the 30-inch low service pipe.

BACK FILLING TRENCHES.

BY E. A. W. HAMMATT, C. E.

[*Read Dec. 8, 1897.*]

As my experience and observation has been chiefly in connection with contract work in suburban or country towns and cities, it may well have been different from that of some present, and if what I have to say shall bring out a good discussion on the subject, I shall have succeeded in my object.

I think that most, if not all present, have seen trenches back filled in such a manner that the street was left with a ridge from 4 to 7 feet wide, and from 6 to 10 inches higher in the centre than the original surface ; and if you had an opportunity to observe the locality while work was in progress you also noted the fact that considerable material had been carted away as well. This condition of things is not, or has not been exceptional, but practically the rule, and as back filling is too often done it must be expected.

The usual back filling crew of say twenty to thirty men, will seldom have more than five or six rammers, and those do not do one-half the work they might, if intelligently directed. Quantity, rather than quality seems to be the object of the average foreman on back filling. The idea seems to have been that settlement was unavoidable, and that to save labor and expense, the trenches should be left well crowned, and be compacted chiefly by travel.

On the average country or suburban road of twenty or twenty-five years ago, this practice was not so objectionable as it is today, when so much more attention is paid to the shape and character of the road surface and we find such a larger proportion of streets macadamized.

What are some of the results of such practice?

First, we have a very unsightly and often dangerous street to travel over, and one which it will take months to get into respectable shape, if it can ever be done without practically resurfacing the street. Next we get a settlement immediately over the trench

with two ridges or shoulders where the filled material is placed on the undisturbed earth adjacent to it. These shoulders prevent the surface water from rain or melting snow from reaching the gutter, and confine more or less of it to the hollow over the trench, where it must soften the road surface and result in making such hollows and depressions worse.

Third, if by accident a large part of the original road surfacing material does not get carted off as surplus, it is placed in these ridges and in the crowning of the trench, and gets carried off when these are picked down, as they must be, thus robbing the road of that which should be most carefully retained.

It is customary to insert a clause in specifications, that a contractor shall keep his work, including road surfaces in good repair, for say six months after the completion of his work and make good any settlement which may occur during that time, the work to be in all respects in good condition at the end of that time.

In my opinion this clause is responsible for at least a part of the trouble. The contractor will usually say, and I think with reason: If I am to be responsible for six months, and must make good all settlement occurring during that period, as a matter of economy if nothing more, I must leave my trenches with a good crown—I can not afford to come back here every week or oftener to refill every little settlement that may occur; and if at the end of the six months the trenches have not settled down level, I will then cart off the surplus. If they have settled below the level, I will make them good.

Still another result of this method of back filling is that usually a crust is formed on the top of the trench, and when the shoulders above mentioned are removed, or the top of the trench cut down, this crust is broken and water soon finds its way under it, and considerable settlement often occurs. Usually this does not take place until after the time limit during which the contractor is to keep the work in repair has expired; and so the town has to stand the expense of doing work which it was supposed had been paid the former to do.

I claim that this is all wrong, and that better results are not only possible, but that we as engineers and superintendents should see that they are obtained.

Back filling should be done with the object of protecting the pipe or other structure and restoring the surface as nearly as possible to its original condition *and in permanent form.*

Let us consider for a moment some specifications regarding back filling.

Date 1875. "Earth filled into the bottom of trench, under and to the top of the pipe shall be carefully packed and well rammed with proper tools for the purpose.

"The earth filling above the pipe shall also be sufficiently packed and rammed to prevent after settlement; it shall be moistened when deemed necessary by the engineer and the material shall be free from stones over 6 inches in diameter. In streets and roads, the class of surface before existing shall be replaced so as to be in every way equal to that surface in material and workmanship, and satisfactory to the engineer."

The difficulty with this seems to me to be partly in the different views of different men as to what will constitute "sufficiently packed and rammed to prevent after settlement," thus raising a question during construction which cannot be definately settled until construction is over, when it is too late to do any good, and the omittance of any reference to the relation vertically between the original and the restored surface.

Date 1882. Another example is as follows: "Great care shall be had in refilling trenches, that the earth is carefully packed under and over the pipes and that the surface or road material is carefully replaced for 18 inches in depth."

It would seem as though under this specification—"most any old thing" would fill the bill, and as I recollect it, when I saw some of the trenches, I should say it did.

We next find a requirement that the back filling shall be put in in layers, not exceeding a certain thickness (variously stated to be from 4 inches to 2 feet) and thoroughly rammed or puddled.

This, I think is a move in the right direction, if the thickness is not made too great; but it is very hard to get it honestly done.

Then comes the attempt to regulate the proportion of rammers to shovelers, and in this connection I would say that one superintendent of streets remarked to me one day: "Hammatt, why do you water works men always get the cart before the horse? You put about five shovelers to one rammer on back filling, when you ought to put

five rammers to one shoveler. Then your trenches might stand."

We all know that authorities say that earth taken from bank and put in fill will shrink, and I think most of us have had an experience in setting a post, that after placing the post in the hole, we could pack in all the dirt excavated, and like Oliver " want more."

This raises the question, why cannot we get more of the material excavated from trenches, put back. I venture to say that we can, and I understand that in at least one case, all the material excavated was put back, and no ridge left. It is scarcely necessary to say, there was no after settlement.

Some authority states that the average shrinkage of various earths is about as follows:

Gravelly earth	8	per cent.
Yellow clayey earth	10	"
Light sandy earth	12	"
Puddled clay	25	"

If this is correct, we should have in a trench 5 feet deep and $2\frac{1}{2}$ feet wide, giving 12.5 cubic feet per running foot, a shrinkage in the case of

Gravelly earth	equivalent to	a depth of	0.40	feet or	1.00	cubic feet.
Yellow clayey earth	"	"	0.50	"	1.25	"
Light sandy earth	"	"	0.60	"	1.50	"
Puddled clay	"	"	1.25	"	3.12	"

Taking into account the average thickness of water pipe of the various sizes as given by the tables of certain foundries, we find that per foot, the following is the number of cubic feet of space occupied by the pipe:

6-inch	about	0.27	cubic feet
8	"	0.44	"
10	"	0.69	"
12	"	0.96	"
14	"	1.29	"
16	"	1.66	"

From the above it would seem that when the pipe laid are not larger than 12-inch, we ought to be able in the average water pipe trench, to get back all the material excavated and leave no ridge, and that even with 16-inch pipe the surplus ought not to exceed about 140 cubic yards per mile of line—or 2.6 cubic yards per 100

feet. It would indicate also, that with 6-inch pipe, it would be possible to refill all the excavated material and leave about 4 inches in depth of trench to be refilled by borrowed material—or with 8-inch pipe about 2 inches. How often is this done? Different materials require different treatment in order to get the best results in back filling. Therefore I question the advisability of too much detail as to methods in drawing specifications.

If I recollect correctly, Mr. Fitzgerald, some years ago, stated as the result of some experiments conducted by him, that in all cases he secured the best results by dry ramming in thin layers, and Mr. McClintock found the same thing with regard to sand, gravel or loamy material, but would use water in clay or hardpan. We must remember that in these experiments, a considerable admixture of brains was also used, and that with the ordinary labor employed in contract work we can expect but little of this commodity.

Thorough ramming is hard work, especially with the style of rammers in common use, and the average laborer will do as little of it as he can.

I am inclined to think therefore, that in general, better results will be obtained by the liberal use of water than by trying to depend entirely on dry ramming; but if water is used, it must be used liberally to do any good, and even with its use a certain amount of ramming must be done.

I think too that better results in ramming would be obtained by the use of a rammer of different shape and weight from that commonly employed. The rammer in common use weighs about 20 to 25 pounds, and has a diameter of about 6 inches. As ordinarily operated by the man using it, it is lifted about 2, or possibly 3 inches and allowed to fall, giving a blow representing the energy of say 5 foot pounds, distributed over an area of about 28 square inches. A rammer weighing 5 to 6 pounds lifted 1 foot would do the same work, and if some muscular energy were added to the downward blow, would do more. Now the lighter tool could be lifted much easier, the man's muscles would not get tired so quickly, and in my opinion a rammer having an end section not exceeding 8 to 10 square inches and weighing not over 6 pounds, would give far better results than those in present use.

In using any form of rammer, it must be remembered that the

ramming will affect but a comparatively thin layer, and so I think we are justified in requiring the back filling to be done in layers not exceeding 4 inches in cases where ramming is depended upon to settle the trench and thiner layers would be better in most cases. As much care should be taken in back filling trenches for house connections or service pipe as for those on the main line. I recall a case a few years ago, where I was notified that the contractor doing some work under my direction, was not properly back filling his trenches, as complaints had been received of dangerous holes on a certain street. Upon investigation, I found that a service pipe had been put in the day before by the superintendent of the works, and the trench back filled sometime in the afternoon. When I reached the place the following morning, the service trench, from a point over the main, clear across the street had settled, parts of it all of a foot, and none of it less than 6 inches, and the only depression I could find on the main line, was at this service. This simply shows that contractors are not the only people who sometimes slight their work.

To sum up, I hold that back filling should be done in such a manner that where the pipe does not exceed 12 inches in diameter, all the material excavated shall be put back into the trench, and the surface left smooth and with no appreciable ridge, care being taken that the original character and quality of the road surface is restored. When larger pipes are laid it would be comparatively easy to fix the amount of surplus material which would be allowed, which surplus should not contain any of the original surfacing stock—which should all be used to resurface the trench. In no case should the material used in back filling be allowed to be spread wider than the size of the trench excavated, as if this is done, shoulders which will retard or prevent surface water from reaching the gutters, are unavoidable, and they must eventually be picked down and removed. This is more expensive than to refill a slight depression, and usually means the carting off of road metal which ought not to be removed. I also believe that instead of requiring the contractor to keep the trenches in repair for six months, a certain percentage of the contract price should be retained for that length of time for the purpose of making repairs which may become necessary, but that the repairs should be made by the town,

DISCUSSION.

Mr. Hyde. In our city if we fill trenches higher than the grade of the street there is trouble. They require us to leave the trench at the same level as the old road bed, and we usually have very little trouble in doing that, by putting in plenty of water, and getting about all of the material back, and most of the time all of it back, except, of course, in clayey ground where we can not use a great deal of water. We usually do use water enough to carry the dirt all around the pipe and perhaps a foot or so above, but we can't wet it much more than that because it would leave it muddy. Then it has to be rammed. But otherwise, on mains and service pipes, we usually water, and if it is grass ground we take up the sod and lay it one side, and then the loam, and then throw the gravel on the other side, and we put the gravel back with water, and lay the sod back even with the turf. In nine cases out of ten that can be done.

Mr. Hammatt. There is one point I hoped I might get some light on. I have had the greatest trouble in back filling a trench in pure clay, and I hope there is somebody present who can give some information as to the best method of handling that kind of material. You take a clay which will cut out, like a cake of cheese, and throw it out onto the bank, it lies there in lumps, and there is just moisture enough in it so it won't break up, and when it is thrown back into the trench, if you try to ram it your rammer slips over it like so much ice or grease, and water won't have any effect on it, as usually tried at least. I hope there is some one who can give me some idea of the best method of handling that. I suppose if it could lie on the bank long enough to get dry and break up, you could put it back all right. At any rate, I know a material holding a good deal of clay that will dry out and pulverize, and can be put back about as well as anything I ever tried. But you take the clay such as I first mentioned, and I don't know how to get it back in any decent sort of shape, so that there won't be any settling. I never succeeded in doing it and I have never seen it done.

Mr. Haskell. The gentleman has covered the ground perfectly in my opinion when he suggests the idea that the nearer you get it pulverized when it is put back the nearer you come to getting a good job. His statement about putting in four inches in depth at a time and ramming it could only be bettered, perhaps, by changing it to

putting in two inches at a time in clay. Any amount of moisture in the clay will make the work of getting it back more difficult. It is entirely impossible to ram clay that is moist, and the greater the amount of moisture the more impossible it is. I have found it almost impossible to get back the whole of certain clays. There are gravelly clays that you can put all back. Any other material I have ever found in our streets can all be put back, even if you should dig an excavation 25 feet deep for a 12-inch pipe. The only difficulty in getting back the material is requiring the men to do it. It is perfectly feasible to do it, and we always oblige our men to do it. Where we do the work by the day, and all of our work is done by the day, we put the whole material back except in certain clays. There are some clays we don't succeed in doing it with, which I have never been able to get back.

Mr. Winslow. I can't give any experience in the clay, but perhaps I can give some experience in other soils. My method used to be to put the earth back and ram it, and I found that Mr. Hammatt stated the fact when he said that a rammer didn't work well in the hands of the ordinary laborer; it is too much work, and the heavier the rammer is, the poorer the earth is rammed. I used rammers weighing from 8 to 10 pounds, and found those worked better than the heavier ones, but those didn't work to suit me. The outcome was that I put enough water in the trench so that when the material was thrown into it, it would sink in the water, and that would wet it thoroughly, and in most grounds it would not settle after being filled. The last of the trench filling I would put in dry, and ram it, so as to give a chance for teams to pass over without getting into the mud. But even that did not really suit me. I have found that the contractors whom I had to deal with for the last year and a half, will do all that is required on the face of it. They will either ram the earth put back, or they will put water to it "in sufficient quantity?" The question is, what is a sufficient quantity, and I find that where they pay 25 to 30 cents per 1,000 gallons for water to put into a trench, their idea of a sufficient quantity is very different from mine. I haven't been really satisfied in a number of cases where it has been done. They say they have the roads to take care of for six months after the work is done; the rains will settle it if there isn't sufficient water, and then they will fix it up. The consequence is that water is used rather sparingly in a great many cases, and with-

out doubt there will be some places to be fixed up within the six months specified.

But in speaking of putting in water to settle the earth, I was shown a scheme this last summer that I think is the best for puddling a trench of anything I have seen.

On Massachusetts avenue, Cambridge, there was a contractor from Medford who put in a 48-inch pipe in a trench averaging, I should say 12½ feet deep. It was deep enough so the 48-inch pipe went under all other water mains and sewers, and in fact all the pipes of the city of Cambridge; none of them were removed. The contractor wanted to fill the trench with no ramming and with no water. I asked him what he took me for? Well he says, "I can do that, and I will make it all right." I said, "how will you do it?" He said, "I will shove a pipe down into the ground and I will completely saturate the earth with water, and it will put it back there so it will not settle at all after I get through, and after I put a steam roller on."

The result was I allowed him to do the work that way in Cambridge. I talked with my division engineer with regard to it. He didn't take kindly to it, but we finally concluded we would let him try a little to see how it worked. Accordingly he filled the trench with this sandy material, or whatever it was, it works the same in all cases. He filled the trench within about a foot, and then hitched onto a hydrant, with an ordinary fire hose, with a play pipe about 20 inches long with about an inch and an eighth nozzle, I think. A 2-inch meter was attached which allowed only about 75 gallons of water a minute to go through the hose. He would shove the pipe down so it would come within 3 feet of the bottom and let it play until the ground settled, and then he would pull it out and shove it down again. When the ground stopped settling and the water came to the surface, he would start over again 4 or 5 feet away and do the same thing, and so zigzagging along up the trench. After getting all the water in he wished to he would then even it off, put on his top material and use rammers, and leave it fairly well crowned. This trench was 7 feet wide, and after letting it stay for a few days, perhaps a week, he put a steam roller over it. The consequence was it put the street down, very nearly, if not quite as well as it was before, and I doubt if it settles a great deal in time to come.

There is another matter to be considered, and that is the cost.

In Somerville, this contractor paid $200 for the water to puddle the trench, using what he wanted. In Cambridge he paid for it at the rate of 30 cents a thousand gallons, and he puddled the trench satisfactorily, and his bill was a good deal under $200, which was the price which they wanted for the water to take it in a lump sum. And you can see that to fill the trench so that when the gravel was thrown in, it would fall in the water and be thoroughly wet before it would go to the bottom, requires a surplus of water over and above what would be required to simply fill it to saturation.

Mr. Gilbert. I am a firm believer in the use of water in filling trenches. I think its use cheaper than ramming and it is much more effectual in my opinion. But I believe you have got to use the water very liberally. In my experience the more water you can get into a trench and not have it overflow, the better job you can do. Of course it makes some difference what the material is that you have to put back. Our streets are mostly macadamized, and we are obliged to be very particular to get all the material back, and with the size of pipe that we lay, by taking pains and using plenty of water, we can do it. Sometimes in putting in services it is almost impossible to get water, and in that case we do it by ramming. But it is a very difficult matter I find to ram material around the pipe, or in any bad place, and get it all back, so but what it will settle some afterwards.

I had an experience last week. I dug a trench across the street about 50 feet long, and had the dirt all thrown out, and one of those cold nights it froze up, and it froze from 3 to 4 inches deep all over that dirt which was to be put back. After putting in the pipe, the workmen began to pick up the dirt to put it back, and it was in large chunks and very solid. I hardly knew how I was going to get it back, because it was where they had got to drive over the trench immediately, and I wanted to get it back in as good shape as possible. The idea struck me that if I would take all those large frozen chunks and throw them in the bottom of the trench, I might settle the fine dirt around them and get it all in in that way. So I had it all picked over and had all the chunks thrown in the bottom of the trench, and then we filled the trench about two thirds full of water, and then put all of the fine stuff back; and without using any rammers at all we got it all in and got it down level with the grade of

the street in good shape. I think it is very much cheaper than ramming without water.

Now speaking of filling trenches when you are laying mains. Of course if a contractor takes a job to lay a line of pipe, he makes his price according to what he has got to do. If he has got to put the material all back and get it down to the surface, he has got to get his pay for it, of course. Now, in back streets, where there isn't very much travel, of course the cheapest way for any town is to throw it back and let it settle itself. It makes rather a bad looking street, but I notice when the work is done in the fall, by waiting till spring it gets down in good shape, and it doesn't cost near as much as it does to pay the contractor for ramming it.

Mr. E. A. Taylor. We have found the method which has been mentioned, of filling to near the surface and then puddling, the most satisfactory way we ever tried. This plan which Mr. Hammatt suggests, of having five rammers to one shoveler can't be carried out at the present contract prices. Last week I had occasion to fill a trench with frozen ground, and some of the lumps were a foot in diameter. I would like to ask if anyone can suggest an economical way of treating them where there is no water to be had?

Mr. Hammatt. My friend suggests that the contractor can't afford to do the best work at the present prices. I think that is very doubtful myself, and I don't think we ought to pay present prices. I think myself it is poor economy for a town to have its work done in the way in which it is too often done, simply to save a few cents per foot on the cost of laying the pipes. I think they have to pay more in the end for fixing the streets than they would if they paid enough to have a good job done in the first place.

Mr. E. A. Taylor. I filled about two miles last year with a road machine, just scraping the dirt in, with no attempt to puddle or anything. We just scraped it in and crowned it over, and that was much cheaper than any puddling or tamping we could have done. It settled the first rain, and we ran the machine over again to fill the holes. We ran it over three times on one street. It was much cheaper for the town, and was satisfactory to them.

Mr. Haskell. I suppose that was in a town where the original condition of the streets, perhaps, was fully as bad as that left them in.

Mr. Fuller. At Winchendon last year, the contractor back filled his trenches and crowned them up. He filled them with the scraper, and then took a four horse team and loaded it heavily, and drove it along, allowing one wheel to run over the trench, and it compacted it and made a very good job of it.

Mr. Haskell. The trouble with that sort of ramming is this: It will do a pretty good job right at the time, but it don't have any effect for any depth down into the trench. You can put a tumbler or a fine glass jar down two feet deep, a foot in diameter, and you could run a pretty heavy load over it and you wouldn't break the glass. That will show you how much effect it would have below the immediate surface that that wheel ran over; it certainly wouldn't extend down over 8 inches. It would get the contractor out of it very likely, but by next spring the trench would be back again just as bad as if that wheel hadn't run over it.

Mr. Fairbanks. I represent Winchendon. Those trenches were filled with a scraper, as Mr. Fuller has said, and a four horse team was put on loaded with stone. At least 12 miles out of the 13 were filled in that way. Then they took the road scraper and went lengthwise, after the dirt was scraped in; and most of our streets were in as good condition in one week after the pipe was laid as they were before, and they have been ever since. They have gone through one winter and almost two summers.

Mr. Gilbert. I had a steam roller run over a gate box the other day, and I guess if the gentleman had been there he would have made up his mind it went to the bottom.

Mr. Haskell. Anybody who has done much of any street work ought to be very well aware of the fact that he can't tell very much about what is under our streets. I had occasion once to dig a hole in a street where they seemed to be a very good surface. There was a sewer laid about 14 feet deep, and a team came along by and broke a hole through. The hole at its first appearance didn't seem to amount to much, but we put in 35 double team loads of small stones in filling that hole. The surface of the street was, as this gentleman says, apparently very good, but without a doubt there had been a small opening in the sewer and the under material had gone down into the sewer and been carried away. It didn't show on the surface at first, but time revealed it.

MR. L. A. TAYLOR. I had an experience in Worcester. There was a sewer built about 13 feet deep through clay—hardpan, and the material was replaced by shoveling and some puddling; I think there was no ramming done, but it was replaced in fairly good condition. This work was done during the summer, and the next spring the street was paved with the ordinary square block paving. Twelve years after that—I was at that time in charge of the Worcester water works as superintendent—I was driving out to one of our reservoirs one morning, and I found that street for about 1,000 feet had settled from 8 inches to a foot. Well, the solution of the thing was this, that the pavement had made a comparatively watertight crust over this trench, and the clay underneath had become gradually saturated, but it had taken 12 years for it finally to drop down and compact itself. I doubt if anyone in the city of Worcester except myself knew the occasion of that, but I knew all about it.

THE PRESIDENT. A six month's guarantee didn't amount to anything in that case.

BACK FILLING TRENCHES.

BY E. H. GOWING, BOSTON, MASS.

[*Read Jan. 12, 1898.*]

I have been asked to tell what I know about back filling. It isn't much, and, after the paper read at the last meeting, it will appear to be very little indeed.

One item, however, seems to have been left out of the consideration, and it is an important one, too. It is the expense of having back filling done as the author of the paper referred to says it should be done.

This same matter of cost is, I think, too often left out of the question; as in the case of installing a high duty pumping engine in place of a low duty engine, when the interest on the saving in first cost, to say nothing of extra cost for repairs on the more complicated machine, is more than the increased cost of fuel, etc., required by the low duty engine; or, as when additional water supply for a city or town is obtained at great expense, when a less amount of money invested in meters, would stop the waste and do away with the necessity for the increased supply.

There is no question in my mind but that back filling can be returned to the trench in such a manner as to prevent after settlement, etc., etc., but does it in every instance pay, and are the authorities whose money is being spent willing to stand the expense?

An instance was reported to me of a contract being taken where Mr. A was the engineer, and where it was supposed that he would interpret the specifications, including the clause regarding back filling, and that he would interpret this clause in that town as he had previously done in others, and by the way, as he has done since. When the work was begun, in place of engineer A, the contractor found that Mr. B was to interpret the specifications, that his ideas were entirely different from those of engineer A; that he insisted

upon having the clause referring to back filling carried out to the letter, and according to his own ideas, and without any reference to those of engineer A. The contractor was caught, and in that case, the authorities got their back filling done as Mr. B thought it should be, and without paying for it. You may say the contractor was at fault in not bidding upon doing the work in the manner called for by the specifications. That opens up an argument upon which much might be said. For the purpose of this paper, it is sufficient to say that not one pipe laying contract in a hundred is awarded to the contractor who bids on doing the work strictly according to a literal construction of every clause in the specifications.

In the case of streets paved or carefully built, back filling should be carefully put back, and the original surface restored as near as it can be. The authorities should pay for it, and the contractor should make his bid high enough to cover the expense. But, in the case of country roads, where the pipe is frequently laid outside of the traveled part of the road, where but little expense has been incurred in building the road, where the original surface, as likely as not, is of inferior quality to the gravel found beneath the surface, I consider it quite unnecessary to go to the expense required by a literal reading of the average clause regarding this part of the work. When the pipe line crosses a street, more care should be taken; and, in the case of service pipes which almost always cross at right angles, it is desirable that sufficient precautions be taken to prevent too great after settlement.

In the spring of 1892, I wrote some specifications for pipe laying and called for a price per foot for pipe laying with the understanding that the back filling should be done in the manner customary in country towns, and, in case it was required, another price for thoroughly ramming the back filling. Practically the same specifications were used in two towns. In one, 2,500 feet were required to be thoroughly rammed; in the other, none. In one town there were four bids; two bids were five cents per foot and one each two and three cents. In the other, six bids; four of which were five cents, and one each, two and three cents per foot, the lowest bidder in each case bidding three cents.

Through the kindness of Mr. Fuller, who writes contracts with

an item for specially ramming back filling when required, I am enabled to give the prices bid for thoroughly ramming back filling in two other towns. They are as follows: In one town, out of eleven bids, there was one, eight cents; three, five cents; four, three cents; one, two and one-half cents; one, one and three-quarters cents; and one, one and one-half cents. The contract was awarded to one of the three cent bidders. In the other town, out of five bids, there were two, five cents; one, four cents; one, two cents; and one, one cent; awarded to the last.

These figures give some idea of what contractors of experience think it costs to back fill so there shall be no after settlement, and some idea of what should be added to the estimates for that purpose.

Now, as I said before, I do not believe this extra expense is warranted in the smaller towns. In a system having, say, ten miles of pipe, the additional cost would be from \$1,000 to \$1,500, without the work being any better. I think I say this advisedly, for those interested in works in such towns have, in almost every case, expressed themselves as satisfied with the work; and, from my contact with water works officials, am sure a large majority of them would prefer not to pay \$100 to \$150 per mile to have the trenches back filled in any different manner from what they were; for, in many towns, even such sums are considered worth saving.

I would like to protest against the form of the back filling clause frequently inserted; for I think this clause, as other clauses, should say just what it means, and mean just what it says, so that the bidder need not take the personal equation of the engineer into account at all, or have to guess as to the probable effect of having an inspector who will or will not enforce the specifications literally. The specifications should state how the back filling is to be done, and then it should be done that way. When the specifications say that it must be spread in 4-inch or 6-inch layers and rammed with heavy rammers, the contractor should not be allowed to scrape it in with a horse-scraper. Please understand that I think it right, in many cases to use scrapers; and were I building works for myself, or acting as engineer, would allow it when proper; but would try to write the specifications so that I would not pay the same price for

having the work done that way, as I would expect to pay for more thorough work.

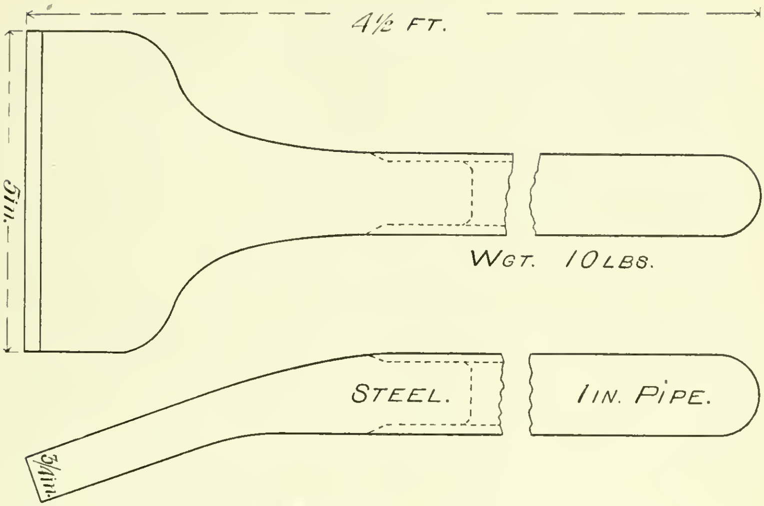
I remember seeing some back filling going on, some years ago, where twelve men were shovelling frozen earth, and two men were ramming with the tools and in the manner spoken of in the paper referred to. From my point of view, ramming, in that case, meant simply an unnecessary tax of $3 per day on the contractor, without the slightest benefit to the town for whem the work was being done.

You who have never undertaken a contract, may think the contractor likes such little things; but were you in his place, would not you think it was worse than foolish to be obliged to make the outlay when neither party to the contract was getting any benefit?

The author of the paper referred to says: "I hold that back filling should be done in such a manner that where the pipe does not exceed 12 inches in diameter, all the material excavated should be put back into the trench, and the surface left smooth and with no appreciable ridge, care being taken that the original character and quality of the road surface is restored," and I would simply add, "where the original character and quality is of such a character and quality as to require it, when it is distinctly understood beforehand that such restoration will be required, and when the authorities are willing to pay for it."

Speaking of the use of water for tamping, of course that is all very well in the case of ditches opened for any purpose in streets already supplied with water; but what will you do when the works are first put in, and when, as is frequently the case, the pipes are all laid before the pumps are set up and in commission? In that case, water could only be obtained at considerable expense; and it is just this expense which I believe, in many cases, we are not warranted in incurring.

What is said, in the former paper, about the tools used and the manner of using them, is true. I believe a rammer more like those used for tamping ties in railroad work would make a much better tool than the rammers now used. To show my idea of what a rammer should be, I have brought one to be used when required. This was made especially for tamping under large pipes which were laid to line and grade and supported on blocks and wedges.



RAMMER FOR LARGE PIPES.

The cause of the listless manner of men using rammers, one need not go far to find. What contractor, in the above instance cited, would put any but the laziest men on the rammers, and even the stupidest laborer, American or foreign, knows that he is mainly there for form's sake, and can you expect him to put any interest in the work? The fact is, "human nature" is a factor in work. Even contractors and their laborers have some of it; and when this important factor is taken into consideration and allowed for, there will be fewer differences between engineer and contractor, better work will be done and every one better satisfied.

DISCUSSION.

MR. FULLER. I think there is a good deal of justice in what Mr. Gowing has said, and it seems to me it would be much better in writing specifications to divide the matter into two parts, or two sections; that is, have a price for a ditch that is to be filled and rammed only under the pipe, and another price where the entire ditch is rammed. I have used this method in two cases and it has worked very satisfactory indeed. I think the trouble with the old style of specifications was, that the water commissioners, who knew very little about the thing and thought that they must have everything done as was specified, which, of course, was all right,

insisted on having a great deal done that was unnecessary. Now if certain parts of the streets require that the trenches shall be rammed, let them be rammed, and let the contractor get the price which should be paid for doing such work ; and in other parts of the town, where there is little travel, where the roads are poor, it seems to me it is unnecessary to do much ramming. In the course of a few weeks or a few months the street will get down to about where it was in the first place, and it will be just as good as it ever was, and just as good as if it had been rammed down flush with the surface. I don't think I ever knew of a pipe being broken after it had been laid, because the trench had not been entirely rammed. So it seems to me it is much better to allow the authorities, the water commissioners, or whoever the persons in authority are, to say what streets and what parts of the streets they will have rammed, and let them be rammed, and let the contractor get his pay for it, and let the other streets go without being rammed so that the top is flush with the old surface. In that way, as has been said, a great deal of money will be saved, which ordinarily can be put into some other part of the work to better advantage.

Mr. Richards. I agree with Mr. Fuller that the ramming should be paid for, but as to where it should be paid for, it seems to me that it is largely a question of how much risk you are willing to take. For instance, if your ditch is improperly filled and settles, and somebody drives into it, five hundred dollars isn't a very large bill for damages, and that would pay for considerable ramming. (Applause.) If you are willing to take that risk, and are lucky, and nobody drives into the ditch, then you are all right, but if you are unlucky then you will wish you had rammed the ditch.

Mr. Hammatt. I don't think I should take issue with Mr. Gowing's remarks, nor, in the main, with those of Mr. Fuller. Yet I think there is one point which Mr. Gowing has spoken of where he has to some extent misinterpreted my paper. While I think I stated that my experience had been mainly in suburban towns, I, perhaps, should better have said in towns near Boston ; and in the majority of such towns the character of the streets is such, that in my opinion at least, they all ought to be rammed. There are undoubtedly places where I would fully agree with Mr. Gowing that the thorough ramming which I advocated might well be omitted, or, at all events, a large part of it. But, as Mr. Rich-

ards says, it is largely a question of how much risk you are willing to take. As to the matter of the use of water, my paper, perhaps, was a little vague. Of course there are cases where it is practically impossible to get water to use to advantage. When I wrote the paper I had in mind more particularly the statement made some years ago by Mr. McClintock, if I remember rightly, advocating dry ramming entirely; and the point I wished to make was that with the ordinary contracting work you would undoubtedly get better results by using water than you would with dry ramming with the present facilities.

Mr. Fuller. I would like to say just one word in respect to what Mr. Richards has said in regard to accidents being caused by lack of ramming. In all my experience, with about a dozen different systems of water works, I don't remember ever having a single law suit growing out of any accident that occurred because the trenches were not entirely rammed. There may have been little accidents where a few dollars paid the bill, but there has been nothing at all serious, nothing where the money paid out would compare with what would have been paid for the extra ramming.

Mr. Richards. Mr. Fuller has been very fortunate, and he is to be congratulated.

Mr. Gowing. I think I have been just as fortunate. I have had to do in one way or another with between 250 and 300 miles of pipe, and I remember but one case where there was any accident which really cost anything, which could possibly be laid to lack of thorough ramming in the ditch, and I am not so sure about that, because it occurred in a low place after a heavy rain, and the ditch was filled up with water. It was thoroughly puddled, and after it was dried out there would have been no trouble. But a team ran into it one Sunday morning, (when the people had no right to be out under the law), and on account of the ditch being so thoroughly puddled and wet, the wheels sunk in and a woman's dress was spoiled, and it cost $50 to settle for that. But it is the contractor who has to pay for all these things, he has to take all the risk; it doesn't come on the town.

Mr. Haskell. Of course, as we are talking this matter over we see all sides of it, and I think we are all aiming to get at the same thing. My idea is that the engineer should write the specifications to cover the particular work there is to be exe-

cuted. Out in the woods, where the road has a good many dangerous places in it, as we may see in riding around in the country, there are undoubtedly a good many places where you could put the dirt back with a scraper and leave the street better than it was before you went there, Any sort of work would *go* there. But I have seen a good many instances in the city where water pipes have been laid in paved streets, and I have sometimes as late as a year afterwards, seen places where the paving had settled down so the street was dangerous. I have known cases where hundreds of feet of paving had to be taken up, and more material put in and the street repaved. I have known that to be done four times on one street. Now, if the work had been done properly the first time, even at quite a heavy expense, it would have been on the whole cheaper, than the final cost of the work. As to the risk of expensive results from accidents occasioned by poor back filling in trenches, I can cite one instance where a contractor put the back filling into a trench in the street, and there came a storm and it settled, and he had to pay $10,000. A man driving a milk wagon came along in the morning and tumbled into the trench, the team was smashed up, and the man was badly smashed up, and there was a $10,000 verdict at the end of a lawsuit.

The President. Mr. Gowing, have you anything to say about that? You see the contractor has to stand it.

Mr. Gowing. He can stand most anything; he has to. (Laughter.) I do not want to be misunderstood as entirely disagreeing with Mr. Hammatt, for I intended to bring out the idea that in certain places it is necessary and desirable that the trenches should be back filled as well as they possibly can be. In such streets as Mr. Hammatt speaks of, in the vicinity of Boston, I should believe in doing it as thoroughly as he would; but I mean to say there are places out in the country where I do not think it is best to do it in that way.

Mr. Chace. I should like to ask either Mr. Gowing or Mr. Hammatt whether they believe in putting back the back filling in such a way as to leave the surface of the ground flat when they get through, or whether they would leave a small ridge to allow for future settling.

Mr. Gowing. I meant to leave a mound. Of course when back filling is put back in that way it means it has got to be watched and looked after. I did some work a year ago, for a gentleman who is

in the room, and after we got all through I said to him, "Now, that ditch is going to settle some, and we are not to be in town; won't you look after it and let us know what the bill is and we will pay it?" That was satisfactory to him and it was to us, and when the bill comes in, if we are not in the poor house, we will pay it.

Mr. Hammatt. In that connection, from my experience, I believe if the trenches are properly back filled they should be left either flat or with a crown not exceeding 2 inches. And I believe that largely for this reason—I am speaking more particularly now of streets where the surface will warrant the thorough back filling mentioned:—if your trench is left crowned with the idea you are going to have future settlement, and that settlement does not take place, that material that forms the crown, to make your street in proper shape, has got to be picked off and carted away. Now that will either be the very best of the road material, and you are carrying off what ought to be left on the street, or even if it is not road material but any other material, makes an expense either to the contractor or to the town which is unnecessary. It is more of an expense, as a rule, to cart off from 4 to 6 inches of material than it would be to put on 2 or 3 inches of road material if the trench should settle a couple of inches. From the experience I have had with towns they very much prefer to cart in 2 or 3 inches of road material to make the street good, than to pick off and cart away from 4 to 6 inches of whatever material there was there.

Mr. E. A. Taylor. The main point under discussion really is the wording of specifications. I think they should be worded differently according to the different conditions to be met with in different places. One incident will illustrate what I mean. We had about two miles of pipe to lay recently through fields, crossing only one road. The clause which referred to back filling was plainly written for city streets, because it referred to paving, macadam, and so forth. The inspector had one idea about the back filling, and we had another, so the engineer was appealed to, and he said: "Well, it will all depend upon how much you are inclined to kick." We didn't kick much, but the result was we were allowed to back fill the trench without any ramming except where we crossed the road.

Mr. Beals. The remark that the gentleman has just made covers a good deal from the commissioners' standpoint, "how much

the contractor will kick." I never could quite see why it should be put in the specifications that the trench shall be back filled and puddled and tamped and all the material returned to the trench, and then when you ask the engineer why the contractor doesn't do that the answer will be, "They never do it;" and then comes in the point how much the contractor will kick. I think it makes a good deal of difference about the material in the streets. In some of the streets in Middleboro the material is of a very peculiar nature with regard to filling. I have a case in mind that happened on our own works. The job was apparently well done, the material, perhaps all of it, put back in the trench, and the street left with a good surface, and some four years after the work was done, one wet night a hack drove up to a house on the same side of the street that the water pipe was and two of the wheels went into the trench, giving the hack a wrench, and the result was that the owner of the hack got almost a new hack out of it. It needed repairs, and the water board had to pay for it. That was because the trench underneath, the lower part, had settled, and left a good hard arch which stood there for three or four years, until it sunk away one wet night and let the wheels of the hack through. And about that same time we discovered a similar condition of things on one or two other streets. The result was we put our men upon every place where we suspected there was such a settling, and picked the earth all down till we reached solid material, and then carted in new material, and I believe, with one or two exceptions, we haven't had any trouble of that kind since. Our soil is of such a kind that some of it will settle hard and some of it will settle with an arch.

I recollect an experience we had in laying an 8-inch pipe. There were perhaps 300 feet of it, and we had to hurry up because we were right alongside of a store with two or three entrances, where they drove up for loads of grain and other things, and we wanted to get the trench dug and the pipe in as quickly as we could. When we got our pipe in it was approaching night, and we wished to get it filled before night so we hurried up the filling without keeping up to the specifications, (we were doing it ourselves, however, and not under contract), and we filled about 150 feet of the trench leaving it a little crowning. The other 150 feet we had good opportunity to both ram and puddle, and we did it thoroughly, and got all the material in, and it didn't quite come to the level. But it so hap-

pened that within eight or ten weeks we had a horse in that trench that we did so well, where we got all the material in and didn't quite fill the trench, and we had to settle as easily and peacefully as we could, without making any more noise about it than necessary. For you know what a temptation there is if anybody can drive a horse into a ditch without getting hurt, to do so and then claim damages. Our experience in that case was that the work we thought we had done the best was what the damage resulted from.

The material we have is a hard, marly material, a mixture of clay. During the summer time, when dry, it picks up a good deal like cement, and when it is wet it picks up like pudding, soft. There are one or two persons in the room who can appreciate the kind of material we have in some of our streets, and what treatment it needs in filling. I have had the best results from dry ramming, and I prefer a rammer like that which Mr. Gowing has shown us, rather than a round one; because the trouble I have found usually has been where the material has been wet and then dried out and shrunk, leaving a crack between the new material and the old side of the trench, and the water pours down through the crack and softens up the new material in the trench. From the experience I have had, (I haven't had as much as many others here have) I have found that if you ram right close to the old hard earth, so the water won't get a chance to get down there, there is less danger from settling afterwards by the earth filling up with water and softening, than there is if you use a round, heavy rammer and ram the whole trench across. I think I have had better results in just seeing that the edges are thoroughly rammed than in trying to ram the whole.

The President. Mr. Taylor cited a very interesting instance at our last meeting, of the settling of a trench after a long time.

Mr. L. A. Taylor. That was a case of a sewer trench, I think, after eleven or twelve years. The reason that it kept up so long was undoubtedly because the street was paved the year after the sewer was built, and it was probably owing somewhat to the kind of material. As Mr. Beals says, the kind of material is a very great factor, and engineers should, it seems to me, make their specifications according to the circumstances, instead of using precisely the same wording in every case, as they often do. I have laid water pipe, for instance, in Provincetown, where there is nothing but sand about the size of granulated sugar, and there is no more use to tamp

it than there is to tamp water. The trench would be from 8 to 12 feet wide on top for a trench 3 feet deep. I have also done work in Middleboro, and, as Mr. Beals says, when that soil becomes saturated it is almost a quicksand, and when it is dry, after it has been on the bank for a few days, it is almost like concrete. It is precisely the same soil, but the difference is in its being saturated with water. So the character of the material should be taken into consideration in back filling trenches, because there are so many extremes. I have also laid a line of pipe some six or seven miles through private fields. The specifications called for tamping it all, through cornfields and woodland and stumps and roots and all that sort of thing, but of course it would be absurd to do that. Of course where we cross the small gullies and rivulets, we have to look after those places anyway. So it seems to me that in making specifications it is somewhat too common to follow the stereotyped form, and then when the work is let simply tell some of the contractors it will be done about so and so, and some other contractor who don't know about that will take the chances. Of course in suburban towns and cities there is no doubt but that the best work which can be done is what should be done. But in country towns in the northern part of New Hampshire or Vermont or down in Maine, it would be useless to ask them to pay $150 to $250 a mile, which might mean $1,000 or $2,000 additional cost for the works. They wouldn't pay for it, it wouldn't be expected and it wouldn't be necessary.

The President. Mr. Hazard, you have had experience, can't you tell us something about this matter?

Mr. Hazard. My experience has been limited. I agree with Mr. Richards, that we can't afford to have trenches cave in after they have been back filled. My experience has been that if you fill them in a hurry, put the dirt in anyhow, the dirt will form a sort of arch over the top which will stand up for some time, and you will never know when you are going to get a cave in. It may come in one year, and may not come in ten years, as has been said. I have seen sewer trenches which caved in after four or five years. A horse would go along and happen to step very heavily and would break a small hole through, and you would find that the whole trench was undermined, that under the surface there was a cavern, and the top of course, is liable to go down at any time.

I have had several cases where we had to back fill sewer trenches outside of the limits of the water supply. The way we have always managed in such cases has been to fill the trenches up to within about 4 inches of the top of the ground, and then leave them until it rained, and we have almost always got them settled in good shape in that way. Sometimes, of course, you have to wait quite a little while, but we have always thought it better to leave them in that condition for two or three weeks even, rather than to fill them up and have them settle after two or three years. Generally if you leave 3 or 4 inches of depression on top till it comes a good soaking rain, the water will stand right there and settle it down thoroughly. Of course that isn't as good as if you had plenty of water to put in as you are putting in the dirt. I will say I have had the best success in putting back earth by filling the trench about a foot or a foot and a half over the pipe, and then filling the trench up with water and letting the dirt drop down through the water, keeping the trench full of water all the time.

Mr. L. A. Taylor. I think earth loosely put in the trench will settle much quicker than if it is half or two-thirds rammed. Ordinarily, earth which is put in loosely will go down at the very first rain; of course that depends some on the character of the material too.

Mr. E. A. Taylor. As to the practice of leaving trenches open for two or three weeks, that might do where there is slow progress, as in digging a sewer trench; but in laying water pipe, where you put in perhaps a quarter of a mile a day, you couldn't leave the trench open many weeks; you would have to fill it up.

Mr. Hazard. I agree with Mr. Taylor, that it is better not to tamp at all than to half tamp; but even if you fill the trench up loosely, the traffic will harden the surface so it makes a sort of a bridge by the pounding of the horses and the wheels. If rain doesn't come pretty soon after the trench is filled, it will hold up a long time before it settles. In the case I cited it held up, I think, for four years before it went down at all, and after that it settled for about two years. I think it is about seven or eight years now since the trench was dug, and I noticed the other day a depression of about 4 inches along the whole trench. Of course that wasn't as bad as a settlement which would let down a horse.

The President. Mr. Eglee, can you say something from the contractor's standpoint?

Mr. Eglee. I have found in my experience but one way of back filling a trench and having it stay as it ought to stay. One method adopted in city streets is to thoroughly ram the trench. Now, there is only one way to thoroughly ram a trench and that is not by a rammer the handle of which comes up as high as a man's head, but to use a regular paving rammer, a heavy iron-faced paving rammer; and to use that properly you must spread your earth in layers no more than 3 inches in thickness, and you must have at least one rammer to every shoveller, or three rammers to two shovellers, and the men must shovel slowly. That is one way, but even then it doesn't always stay. After years that will settle down and you will have to replace your paving; but that is the best way of ramming. Any kind of ramming where the man takes the rammer and stands in this way (illustrating) and pounds, is not entirely satisfactory; because the usual method of ramming trenches, where that kind of tool is used, is to put some dirt in the bottom of the trench, and the poor men go in there down low so that the taxpayers don't watch them very closely, and they ram just as little as they can. And when they get up to the top, where the "committee of forty-nine" can see what they are doing, then they begin to ram hard and put a crust on top of the earth, and that is just exactly what you want to avoid. You have got all your soft material underneath, and the water works through under this hard surface and attacks all the loose, soft, half-rammed material, that goes down and then you have a nice crust on top for somebody to fall through some day That is the method of ramming usually employed in suburban towns. I have back filled trenches for fifteen years, and I have never rammed them when I could help it I always kick.

There is one method, however, of back filling a trench and leaving the trench absolutely right, just one method, and in employing that method the contractor takes the risk; in fact the contractor takes the risk anyway. What does your contract say? It says that this work must be delivered to the water commissioners at the end of six months or one year, and the contractor takes the chances all that time. Now, when I first began to back fill trenches I laid awake nights wondering if anybody was going to get injured. I don't do that any more, because in fifteen years I have never had but one

accident, which cost me $200, and that occurred in a very peculiar way. I built the water works in a certain town and back filled the trenches, and in front of the post office I rammed it thoroughly. Two years afterwards, when visiting some friends in that place, I drove across the trench in front of the post office, and my horse fell in and I had to kill the horse. (Laughter.) That is the only loss in fifteen years. Now, I will tell you what I think is the best method. It is to take a rammer of the character I have mentioned and ram around your pipe under the bottom of it thoroughly, just as well as you possibly can, and have that ramming follow directly on the heels of the caulkers. Just as soon as the caulkers have finished let certain specially picked men, men who will do this work well, who have no foreman standing over them, but who have been selected to do this work because they will do it well, let them follow right behind the caulkers and ram under the pipe thoroughly. Then fill the rest of the trench just as loosely as you can. Have a slight mound, and lengthen that out so that no one will tip over on it. Then after every rain send your men over this trench and loosen the top of it, and don't let it become compacted, but have it loose so that the water will soak into the trench. That is the best way of settling it. After a winter's rains and snows and frosts have gone over that trench, in the spring time you can go over it and smooth it up and it will be all right then. If you throw your earth into the trench and put water on it, soak it, the earth will shrink away from the sides, just as Mr. Beals says. If you ram it, in most soils you can't ram it hard enough but what a good deal of the earth is soluble in the water that will work its way into the trench. Anything that is soluble in water will be carried down into the bottom of the trench and fill up the little cavaties, and the top of it will finally cave in. You can't ram it hard enough to have it right, because after you have rammed it you can turn a hose onto the trench and work it down. There is only one absolutely sure way, and that is to keep the top of your trench soft, take the risk, and then fix it up in the spring.

Mr. Evans. I believe the trench should be filled half the diameter of the pipe and thoroughly rammed, and then above that, if care is taken to fill in horizontal layers, not allowing the laborers to make hills, as I call them, which allow the dirt to run down and become uneven in the trench, I think your settlement will be so

uniform you will have very little difficulty with it, especially if you mound some 4 or 5 inches above the surface where your trench is. I think there should be great care in seeing that the trench is filled uniformly, and not in uneven ridges. I think there is more trouble from unequal settlement than from any other cause, and that is on account of the way the earth is put in. I do not believe, except in much traveled ways, there is any necessity of ramming the trench to the top. Certainly the way it is ordinarily done I don't believe it does much good. I know I have often said, in going along the trench where they were ramming, that I would be willing to put my watch under 4 inches of earth and risk the glass crystal, and I think it would be perfectly safe to do it.

HANDLING AIR IN A TUBE WELL PUMPING PLANT.

BY D. N. TOWER, SUPT., COHASSET, MASS.

[*Read January 12, 1898.*]

This paper is to give a brief description of the Cohasset Water Works and my experience in fighting air leaks in the wells and suction mains of a driven well supply.

Cohasset is a small town on the south shore about twenty miles southeast from Boston; population about 2,450, this number being quite largely increased in the summer by nonresidents who have summer homes there.

The water supply is taken from 64 driven wells, 2-inch diameter, located in the centre of the town. We have a Blake pump of three-quarter million gallons capacity and a reservoir of one and one-half millions, the latter located at an elevation of 160 feet, which gives an average pressure of 60 pounds. There are about 7 miles of cast-iron mains, 36 hydrants, and 288 service pipes, being an excess of 88 service pipes over the total number estimated at the time the works were built The suction main consists of 478 feet of 10-inch pipe, 676 feet of 8-inch, 459 feet of 6-inch and 289 feet of 4-inch, a total of 1,900 feet of cast-iron, besides the sixty-four 2-inch driven wells amounting to as many feet more, thus giving a total of 3,800 feet of suction pipe.

The wells were driven in two lines about 650 feet in length each, and about 80 feet apart, connected at about the centre, and on this connection is the sand chamber which is 407 feet from the pump. From this sand chamber is a third line extending in one direction only. On these lines the wells were driven about 24 feet apart, and to a depth of between 18 and 38 feet, the first 10 feet through layers of muck, sand and gravelly hardpan, thence through from 8 to 25 feet of clay which overlays a strata of fine gravel about 3 feet in depth, from which the water is taken. Below this gravel is bedrock.

The pump was started December 17, 1886. At that time there

were but few services laid, so there was very little work for the pump. The first year we got along very well, but the next, the number of services increasing and the water in the ground above the clay strata getting low, the joints in the cast-iron suction mains were prevented from being sealed by water, thereby allowing air to reach the lead joints. Then I began to be troubled with air, for as each piston moved towards the water end of the pump, the air that had been drawn in on the previous stroke would be compressed and the piston rod would be seen to jump from half an inch to an inch at nearly every stroke. This was very annoying, and I began to study means of prevention.

As there were 1,900 feet of suction pipe laid from 18 inches to 7 feet deep, and 64 wells that were not gated so that any one or more could be shut off independent of the others, or so that all could be closed to allow a pressure to be had on the mains to assist in locating any imperfect and leaky joints, a difficult problem to solve seemed to be present. I think you will admit that the prospect of finding the leaks was not very encouraging.

Previous to this time I was aided in finding a small leak in the 10-inch line leading from the pump to the sand chamber, and covered but about 18 inches, by a man who was mowing the grass above it. He came to me and said that he heard a funny sound in the ground out in the meadow. "It sounds like a nest of bees," he said, "a sort of whistling noise." I instantly mistrusted the cause, and asked him to show me the spot. He led me to a place over the 10-inch line, where, inside of a circle of about 4 feet diameter, the grass was dry and dead while outside it was fresh and green, caused without doubt by the air being drawn down through the ground and absorbing or evaporating all the moisture.

I set a man to digging, and he soon came to a joint in the pipe. I could very plainly hear the air rushing in and I thought a large leak had been discovered. He brought the calking tools, and as the joint was quite dirty, we washed the lead before calking. In doing so, some of the dirt was drawn into the joint wholly stopping the leak, thus showing how very small it must have been. The joint was thoroughly driven before covering. We then examined all the joints in the line without finding any others defective. We examined the ground over all the suction pipe, hoping to find more dry spots of grass, but found none. I could see that the trouble at the

pump was gradually increasing, and at the sand chamber where the water from the different lines came together, could be heard quite a commotion. My whole thought was how to remedy this trouble. I finally decided, that instead of going to quite an expense in digging to all the joints and connections in the suction pipes, to investigate, with the chances of success very uncertain, as it was quite probable that there might be one or more split couplings in the wells, I would try to overcome the difficulty by removing the air from the pipes before it reached the pump, thinking that in so doing success might be more certain.

With permission from the directors to make my experiments, I had the Blake Manufacturing Co. make a small air pump, 3½x4½x4, which was placed in the pump house. I cut in a 6 on 10 tee in the 10-inch suction main about 75 feet from the pump house. This was placed looking up, and into it was leaded a piece of 6-inch pipe with a plug in the upper end and a 3-foot water glass on the side. From the top of this pipe was laid a ¾-inch pipe to the air pump. I had calculated that the air in the water flowing along in the 10-inch pipe from the sand chamber to the pump would collect in small bubbles and rise to the top of the pipe, and by having a few inches more vacuum on the air pump the air would rise in the chamber and be taken away by the pump. The result was all that could be desired. The air was wholly removed, and the pump would run all day without a kick.

This air pump answered the purpose for about three years, I think, but as the number of services was gradually increasing and more water being needed, its limit of capacity was reached. A larger air pump was then procured and connected to the air chamber with a larger pipe. This answered for a while, but the demand for water constantly increasing, a greater lift was shown by the gauge on the pump. Suddenly, one afternoon, the main pump started up at a speed of about 500 revolutions per minute, more or less, in place of twenty-five, the usual speed. It was evident that some one or more wells of the sixty-four had given out, but which one, and how to find it?

At the sand chamber are three gates dividing the wells into three sections. The next day I had the pump run at the usual speed until near the same amount of water had been pumped as on the day before, as indicated by the register. The engineer was then

asked to stand by the pump so as to be ready to shut down as soon as the air came. I went to the sand chamber and closed one of the gates, cutting off thirty wells, and then went back to the pump house to watch the gauge. As we were then pumping from thirty-four wells, I knew it would soon cause the same trouble as the day before or show more vacuum on the gauge. It was air as before, showing that the trouble was not on the line shut off. We tried the other lines on the following days, the last day being able to pump slowly from forty-three wells with more vacuum on the gauge than formerly. This satisfied me that the trouble was on the last line shut off. We then opened up all the wells on that line and measured the depth of each. I found eight wells that were less than 25 feet deep, one of them being less than twenty. I thought best to disconnect these eight 25-foot wells, which we did, and then all went well. We kept at work and examined about all the wells in the system, but found none that I thought best to disconnect.

Then for a year or more I got along without much trouble, but each year the demand for water increased and there was consequently more air to be taken care of, and soon two air pumps were unable to handle it, some slipping by the tee and so reaching the pump. As one air chamber had proved so effectual, I concluded to put in a second one. This one I put in the pump house so that it could be used in the winter, as I found that with all the ground where the wells are, flooded, as it always is in the winter, there was still some air that needed taking care of. I soon learned, after putting in the second air chamber, that a larger air pump would be required. Such a one was procured, one for business, a 10x8x12.

There has been no trouble since in handling the air to a certain point. I feel quite sure that there is a split coupling on some one of the wells, as I found that we could pump all day by not exceeding 20 inches of vacuum. More than that soon causes trouble.

I often think how an unlimited supply of water from a river or pond would be appreciated, which most of you have. In most cases where there are driven wells there is a pond or river within a short distance, which can filter to the wells, but in my case, there is no sign of good water on the surface of the ground within a mile. I live in hopes of securing an increased supply during this year. Last fall the ground was tested over quite an area, but within reach of the pump. Nineteen trial wells were driven, and we think that by

going about 1,500 feet in another direction we can get considerable more water.

I would say that my way of separating air from water has been greatly improved upon by the use of what is called an "Air Separator," in the shape of a cylinder about 4 feet in diameter and 6 feet high, with a partition in the middle. The separator is set on end near the pump, the top of the partition is on a level with the top of the water cylinder with about 2 feet of space between the top of the partition and the top of the separator, to which the air pipe is attached that connects with the air pump. The suction pipe leading from the wells is connected at the bottom of the separator on one side of the partition, and on the other side, at the bottom, is the connection with the pump. The air pump is intended to raise the water a few inches above the top of the partition, when it flows over in a thin sheet the width of the diameter of the separator, to the other side. The enlarged area of the separator allows time for the air to rise into the space above and be removed by the air pump and the water is drawn to the main pump. This can be seen in operation at Hyde Park, and at Eaton Meadows in the town of Malden.

DISCUSSION.

THE PRESIDENT. Mr. Forbes, you have a driven well system, and perhaps you will say something on this subject.

MR. FORBES. We have no air on the Brookline system. All our wells are more than 35 feet, and I wouldn't have a well unless I could have more than that depth. We have a mile and a half of suction mains, 24-inch, 20-inch, 16-inch, 12-inch and 10-inch, and about 165 wells. We have no air, no air pump, no sand chamber, and nothing of the kind. The whole system is air-tight. We pump at the rate of 5,000,000 gallons in 24 hours while we pump.

MR. TOWER. I would like to ask Mr. Forbes how low the ground water is in the wells in a dry time?

MR. FORBES. It stands 2 or 3 feet below the bottom of the main after we have pumped a few hours, and during the night it generally rises over the main. We have a check valve so the air can't get into the suction; otherwise the probability is the whole main would fill full of air so we couldn't start it. We have no air pump and no sand chamber, and the pipe runs right onto the pump.

Mr. Tower. In a dry time the water in our wells will be 18 feet below the surface of the ground where the wells are driven, and 21 feet below the pump cylinder, and that will be in the morning when we start the pump.

The President. Mr. Evans, will you say something on this subject?

Mr. Evans. I have had no experience with driven wells, but I have seen some up in Lowell. When they started with a driven well system they had a great deal of difficulty. I have watched their engines, and at the end of the stroke they would kick 2 or 3 inches, so you would think the end of the pump cylinder was coming out. They had to put in a large air receiver and an air pump before they could control the air at all. I think their experience was the common one, and Mr. Forbes is certainly very fortunate not to have had that kind of trouble.

PLACING A 10-INCH HIGH SERVICE PIPE ACROSS A RIVER.

BY FREDERICK W. GOW, SUPT., MEDFORD, MASS.

[*Read December 8, 1897.*]

In Medford, as in a number of our New England cities and towns, there are two systems of water supply. The low system, which is supplied by gravity, feeds the central and easterly side of the city, and the high service main passes through the center and feeds the northerly and westerly and southerly sides of the city. Part of the westerly side, being low, about as low as any part we have, is supplied from this main through a reducing valve. In passing from the westerly to the southerly side of the city we were obliged to cross the Mystic river. At the point of crossing it is 130 feet wide and is spanned by a wooden bridge supported by three stone piers. The roadway of the bridge is narrow, and as half of the bridge is in Somerville it was deemed unwise to go over the bridge. The river at this point being pretty well interspersed with a deep bed of mud and quite a collection of large boulders, it made going under the river rather difficult, so we simply did, what had been done a hundred times before, went across the river on the bridge piers.

In doing this we built a staging under the bridge by boring through the planking ; boring a set of holes every 10 feet, about 7 feet apart, and putting through the holes inch rods or bolts about 8 feet long, and on the bottom ends of the rods putting pieces of 4x6 which were bored, slipping those over the ends of the rods and then putting on nuts and washers, thus making hangers to carry the staging. Then we put 2-inch planks across on those hangers, and then took down the stone work on the top of the piers in the line of the pipe, going low enough to get the pipe through. We leveled up the piers, and then placed between each set of piers a set of 15-inch steel channel irons, 36 feet long, about $2\frac{1}{2}$ feet apart, tied together every 6 feet with wrought-iron straps 2-inch x $\frac{1}{2}$-inch. Those straps were bolted on either side of the lips of the channel irons. Resting on the lips of the channel irons on the bottom we put bed blocks of 3x10 pine

at each set of straps, and on top of these blocks set 4x6 pine blocks recessed to the curve of the pipe, for the pipe to sit on. Then we took the pipe through from either end, slid the pipe along on rolls on top of the channel irons to their respective places, let them down on the cradles, and put them together in the usual manner. After the pipe had been all put together and tested, a flooring was built under the pipe of two layers of inch boards laid one on top of the other to break joints, simply laid in crosswise on the lips of the channel irons, the 3-inch blocks under the cradles having been rabbeted out on either side so that the second layer of inch boards lapped over onto the 3-inch block, making practically a tight bottom.

After the floor was put in we filled in the whole space around the pipe with charcoal dust packed in tightly, and then by laying stringers lengthwise bolted to the top of each channel iron, we made a roof over the whole structure, nailing $\frac{7}{8}$ matched pine sheathing crosswise, and covering it the same as the bottom, breaking the joints. This made a practically tight box, after which it was painted.

DISCUSSION.

Mr. Whitney. I would like to ask Mr. Gow if he considered any other material for packing the pipe except charcoal ?

Mr. Gow. We did not. In fact we were doubtful at first whether to pack it or not, for the main supplies quite a district, and we had very little fear of its freezing anyway on account of the circulation.

Mr. Whitney. How much thickness of packing have you on it ?

Mr. Gow. There is a space around the pipe of about 6 inches.

Mr. Bates. I would like to ask Mr. Gow if the box is continuous ?

Mr. Gow. The channel irons come within 6 inches of each other, and on the sides we pieced out with boxing. It makes the box continuous. There are four sets of channel irons, and it makes one continuous box the whole length under the bridge.

Mr. Walker. Is there any expansion joint ?

Mr. Gow. No, sir.

Mr. Coggeshall. Does the water ever rise in the river to cover the pipe ?

Mr. Gow. No, sir, it does not. There is a space of some 5 feet between the box and the river at high water.

Mr. Kimball. I would like to ask if that has been subjected to a winter's freezing?

Mr. Gow. Yes, two winters' freezing.

Mr. Kimball. Why I ask is because of an experience of my own at Putnam, Conn. We had a 6-inch pipe boxed, crossing a small stream, a span of not over 15 feet, and we filled the space with sawdust, (I presume the action would be about the same with charcoal) some water got in there, either through a leaky joint or in some other way, and it froze solid with the usual result. We took it out and replaced about three lengths of pipe. This is on a dead end, where there is very little service. We put the pipe back, built a double box around it with an air space without any packing at all, and it has never bothered us since. So it would seem as though air was a better protection against frost than sawdust, and quite likely better than charcoal.

Mr. Taylor. Speaking of packing pipe, I will say that at New Haven, Conn., there is, or at least there was a very few years ago, a line of 20-inch pipe, 800 feet long, that has no covering whatever to it and it never freezes at all. But of course the circulation is constant and quite regular. At Newport, N. H., the 10-inch main passes across the river over a bridge. We boxed that, having a double box with an air space of about 2 inches without any packing. And my experience has been that where there is any probability of any water from leaks or anything of that kind, it is better not to use sawdust and to have the air space alone; because if there is any little leak it will probably work out, and unless there is considerable thickness of material I believe that air is better than sawdust or charcoal.

Mr. Walker. We are speaking about protection, now, and there has been a good deal of talk in the last few years about protection. We have across the Merrimac river, in about the coldest place in the world, at least in this part of it, an 8-inch pipe without any protection whatever. It hangs right up on the sidewalk of the bridge, and we let the water go through there in the winter time and shut it off from the river crossing, unless in case of a big fire. The pipe is under about 90 pounds pressure and it feeds about 8,000 inhabitants. The expansion joint in the middle went just an inch and a half last winter. It is a wrought-iron pipe 600 feet long.

Mr. Haskell. It is probably true that a pipe without any pro-

tection whatever would not be liable to freeze with the water running through it freely, and that explains why the action of the frost has been so different in different places. There would be no danger where there is a large amount of water running through a pipe, and there would be great danger where there was no water running through a pipe. In regard to the best material to use to protect a pipe, I will say we have used almost everything we could think of, and I consider that an air space is about as valuable as any medium we can use, but ordinary concrete, such as they use for concreting sidewalks, is the best material that there is, and tan bark is the next best.

Mr. Walker. I would like to ask one question. Suppose you had two bridges and you were going across both bridges; say the two bridges were 1,000 feet apart and you had an 8-inch pipe going across both of them. Now, wouldn't one of them freeze if you let them both run?

Mr. Cook. I will say for Mr. Walker's benefit, although this may not exactly meet his case, that we have in Woonsocket, 540 feet of 20-inch pipe on a bridge, and about 1,000 feet up stream we have about 175 feet of 14-inch pipe. The 20-inch pipe is not boxed; the 14-inch is with a double box and air space. The first winter after the 20-inch was put across the 14-inch remained open, and I had no trouble with frost. On neither bridge is there any expansion joint, but I have no trouble from the fact that the pipe is independent from the bridge. The bridge travels but the pipe does not. The pipe is fitted on rollers.

Mr. Hyde. In Newton, where we have to cross the Boston & Albany subway in a good many cases over the bridges, we use small cuttings of leather to pack with. I got my cue from Mr. Morse, of Natick. He has used them for a number of years, and he tells me that in the coldest weather when they uncover a box it feels warm in the packing around the pipe. No doubt this is caused by the oil in the leather which, perhaps, creates heat, and keeps the pipe from freezing. Now, at night the circulation across these bridges is very small, and some of our pipes are as small as 6-inch. This will be our first winter's experience, but I think there is no doubt the packing will work all right, although we haven't as much space around the pipes as Mr. Gow speaks of.

Mr. Hammatt. Speaking of packing around pipes over bridges,

if I remember rightly, at the time the Lewiston, Me., works were put in in 1878 or 1879, they had two or three canal crossings. The pipes were carried across on independent bridges, made on purpose to support the pipes. As I recollect it they were first put in a wooden box which was filled with tan bark, and the first winter one or more of those lines caused considerable trouble, and one of the bridges gave way. When they came to investigate the matter they found that there had been some leakage, probably from a joint, the pipe was laid the usual depth through the street, and came up with a quarter turn, and made another quarter turn to go across the bridge. In making those sharp turns there probably was some motion in the joints which caused leaks. The box filled with water and froze solid, and it made so much weight that the bridge gave way. If I recall the matter rightly I was told that the next year they abandoned the packing and used simply an air space, and have had no trouble since. At Gardiner I know we had a crossing over the stream, and we used simply an air space there, although there may have been some tan bark used; Mr. Maxey can tell about that.

Mr. Maxey. We used tan bark and it froze and burst, and then we used simply an air space.

Mr. Cook. We all know that pipes filled with water on certain days in the spring and fall will sweat, you have undoubtedly all seen that, and I don't know of any material that can be used to pack around the pipes but what will absorb that moisture.

Mr. Fuller. We had trouble when the Wellesley works were first built. We filled the box with tan bark, and the first winter the pipes froze up and burst. I have no doubt as to the force of Mr. Cook's suggestion, that even if the pipes do not leak there is more or less condensation, and the tan bark or any other material that is put around the pipes will become moist and freeze. I think in regard to pipes that are exposed it will make a great difference what the supply is, whether it is a ground water supply, where the temperature of the water would be nearly uniform the year round, or whether it is a surface water supply where there is a good deal of difference in the temperature.

Mr. Hastings. In Cambridge we have had a little experience with packing pipes. We have a place there where two pipes cross the railroad, a 6-inch and an 8-inch. Both those pipes were packed

with wool waste. That was some six or eight years ago, and we have never had any trouble since. There is very little consumption in the night, and very slow circulation of the water. I think the wool waste works perfectly. This fall the bridge was taken down and I found the wool waste was intact, it didn't seem to have corroded at all. The idea had been that the wool waste would set up a species of spontaneous combustion and would thus keep the pipe warm, but I do not think that had taken place, as the wool waste seemed to be sound and good. But it served the purpose of an excellent packing for a rather small pipe.

Mr. Cotton. I have used lampblack and air space and hair felt to cover pipes with, and as they have all worked well I really don't know which is the best. For the last four or five years I have been using hair felt and an air space in single boxes, one or two thicknesses, according to circumstances, about three-quarters of an inch of the hair felt wrapped around the pipe and wired or fastened on with cords. It is very convenient to put on, very cheap, and I have never had any pipe freeze, although I have had some in places where there was a very small consumption. I think, although it is probable some moisture collects in it, it evaporates more or less. At any rate I still continue to use it and it has thus far served a very good purpose.

Mr. Maxey. Down in the town of Caribou, Maine, where the thermometer goes to 40 degrees below zero, they have a system of water works where they have a pipe crossing the river, I think it is only a 6-inch pipe. The river is 140 feet wide and the consumption on the further side is not very great. They had it at first boxed in the ordinary way and filled with tan bark, and it froze up solid. Then they practically built a small house across the river and put a stove in it, and were actually obliged to run the stove all the time. (Laughter.)

Mr. Gilbert. I have never had any experience in laying large pipes across rivers, but I had four hydrants which were set for fire purposes near a large factory, and it was very low ground, where the water came clear to the top of the ground all the time. The water of course would work through the drip of those hydrants and fill them up and remain so, and we found that the first winter after they were put in they froze up solid, and they kept frozen nearly all winter in spite of all we could do. The next season we plugged up

the drips in the hydrants, but the water got in there in some way and they froze up again. The next season we built some little houses of matched boards over each one of them, and we have had no further trouble with them at all. You can open the doors of those houses any time, and in the coldest weather in the winter the ground will hardly be frozen around the hydrants. You can use them with perfect safety in the coldest weather in the winter. We have some nine or ten private hydrants in the town around the factories, and the same kind of little houses have been built over them, and I have found just the same result when I have examined them, that the dirt is hardly frozen around the hydrant even in the very coldest weather.

Now, one thing more. I had a service pipe which was put in along a bank, the bank was some 6 or 7 feet high, and this service pipe was put in there 6 feet from the outside of the bank and about 4½ feet deep. It was put in quite late in the fall, and just as soon as the coldest weather came on I had a notification from the gentleman owning the premises that he couldn't get any water. I examined it and found it was frozen up. We dug the pipe up, thawed it out and lowered it nearly a foot and filled it in again. But it was only a few days before it froze up solid again and remained so all winter. I hardly knew what to make of it. After talking with some gentlemen who had had a similar experience, I began to think it was on account of its being so near the side of that bank. Well, the next fall I dug that service up, and put a 2-inch pipe over it the whole length, and I have never had any trouble with it since.

Now I suppose all of you have had some experience in putting in services sometimes where there is no cellar under the building, and we all know it is a very difficult matter in cold places to keep them from freezing. I am always particular in such a place to put the pipe through a larger pipe, and I have hardly ever had any trouble from one of those services since we commenced doing it in that way.

Mr. Stacey. I remember some time ago we had a discussion on the protection of water pipes by various substances, when our venerable friend and brother, Mr. Jones used to meet with us, and his opinion was asked as to the best substance to cover a pipe with to keep it from freezing. He mentioned a number of things he had used, but finally said that according to his experience there were

only two ways to keep pipes from freezing when exposed to the frost, and those were either to let the water run, or to keep the water out of the pipe. Well, perhaps that was a pretty broad statement, but the covering I think depends somewhat upon the condition and the locality in which the pipe is situated. If there is a circulation, it is natural to suppose that the water in passing through the pipe is not exposed to the cold long enough to be reduced to the temperature of freezing; that is, it comes at above freezing from the ground to the point where it enters the pipe crossing and is exposed, and before it has a chance to cool to the freezing point it has passed on its way below the frost again.

Now it seems to me that any fibrous packing that can be put around the pipe, where there is moisture, does not give it much protection. If a pipe lies on a ledge, even if it is below the frost line, the frost will follow the rock down to a considerably greater depth under certain circumstances than it would if the pipe was laid in the earth. So it looks to me that if you are going to cover a pipe with anything at all you want something that is impervious to water, if you can get it.

I have a standpipe set up on a trestle, with a 12-inch pipe leading up to it, 60 feet high. It stands in about as exposed a place as can be found in this section of the country. We protected that pipe by putting sheathing around it, we put a 6-inch air space between that and the pipe, being careful to keep the sheathing away from the pipe so that any moisture on the pipe would run down to the bottom without communicating with the sheathing in any way. Outside of that first sheathing was put an inch of hair felt, held on with brass bands. Then there was a 4-inch air space outside of that, and another sheathing of matched boards, narrow strips. We keep the water in circulation; this is used for fire purposes only, and of course in the winter it would remain practically stationary, and the water would freeze over on the top quite solid and tight; to prevent that we keep enough circulation in the pipe to keep the ice moving. We have used this for two years and haven't had any trouble with it and I don't expect to have any.

I have had some experience with pipes in wet places. On one side of Main street I have a service pipe entering a house, not over 12 inches below the sidewalk, on a ledge. I couldn't sink it any lower without blowing the house up, and if I blew the house up they

wouldn't want the service pipe, so I had to put it in as I did. I packed that solid with tar concrete. I have two other services covered with concrete which have been in eight or nine years, going up a bank where there was a ledge with 2 feet of covering. When the concrete is made, I am particular to have it made pretty rich with tar having considerable pitch with it so it will soon set and stay in place; and then I want it thoroughly rammed and compacted to exclude any moisture from getting into it. In a wet trench you have got to be pretty careful not to get any water mixed up with the concrete in putting it in.

I am going to try the experiment on a 16-inch pipe which I have to lower in a kind of siphon to cross under a subway. We are going to lower the pipe and I propose to lay it in concrete. The only thing I shall have to contend with will be the amount of water, but I am satisfied I can protect it if I can keep the water out until I get the concrete in.

In regard to the protecting of hydrants, the gentleman says he has some where the water comes up near the surface. I have two or three where the water will run out of the nozzle from the drip, and building a house over them wouldn't do any good. I have about a dozen hydrants where the drips are plugged, and I would say frankly I wouldn't give a continental for a drip on any hydrant in the winter. I pump every one. We plug the drip, find the hydrant is tight and pump it out, and then we haven't anything to think of, unless somebody bothers with the gate after we once find it tight. I think from what experience I have had that concrete properly mixed and properly compacted around the pipe, and protected on the ends so that the moisture or water can't get in and work down around the pipe, (and I think that is a very important thing,) is the best material I know of to protect a pipe, and it will last forever almost. But no matter how well the pipe is protected, if it freezes on the end it will freeze right down through the pipe. I have had a pipe freeze in the cellar and out to within two feet of the main, some 20 feet. When we dug down beyond the cellar wall, to be sure we were right about the matter, we didn't find any frost back of the cellar wall for 2 feet, but we had to thaw it out to within two or three feet of the main before we struck water. So no matter how well we cover a pipe, if it is exposed at the ends to the frost it will freeze down through the covering. That has been my experience.

PROCEEDINGS.

QUARTERLY MEETING.

Young's Hotel,
Boston, December 8, 1897.

President Kent was in the chair, and the following members were present:

ACTIVE MEMBERS.

Everett L. Abbott, Charles H. Baldwin, Lewis M. Bancroft, Frank A. Barbour, R. S. Bartlett, George E. Batchelder, Oren B. Bates, Joseph E. Beals, James F. Bigelow, George Bowers, John T. Cavanagh, George F. Chace, E. J. Chadbourne, Charles E. Chandler, G. L Chapin, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, John W. Ellis, J H. Fairbanks, B. R. Felton, F. F. Forbes, Frank L. Fuller, Julius C. Gilbert, T. C. Gleason, Albert S. Glover, W. J. Goldthwait, J. A. Gould, Frederick W. Gow, E. H. Gowing, Richard A. Hale, E. A. W. Hammatt, John C. Haskell, L. M. Hastings, V. C. Hastings, Horace G. Holden, H N. Hyde, Willard Kent, Patrick Kieran, Frank C. Kimball, James W. Locke, C. M. Lunt, J. S. Maxey, Frank E. Merrill, Leonard Metcalf, James W. Morse, Thomas Naylor, Frank L. Northrop, John H. Perkins, W. H. Richards, W. W. Robertson, William Ryle, A. H Salisbury, J. W. Smith, George A. Stacy, Edwin A. Taylor, L. A. Taylor, Robert J. Thomas, Wm. H. Thomas, D. N. Tower, W. H. Vaughan, Charles K. Walker, J. Alfred Welch, John C. Whitney.

ASSOCIATE MEMBERS.

M. J. Drummond, by Wm. V. Briggs.
Deane Steam Pump Company, by F. H. Hayes.
Hersey Manufacturing Company, by J. A. Tilden.
Ludlow Valve Manufacturing Company, by H. F. Gould.
Jenks, Henry F., Pawtucket, R. I.
Lead Lined Pipe Company, by T. E. Dwyer.
Neptune Meter Company, by H. H. Kinsey.
Perrin, Seamans & Company, by H. L. Bond.
Rensselaer Manufacturing Company, by Fred S. Bates.
Robertson, R. A., Providence, R. I.
Smith, Anthony P., Newark, N. J., by Mr. Van Winkle.
Smith, Benjamin C., New York City, N. Y., by F. A. Smith.
Smith, B. F. & Bro., by B. F. Smith and James Martin.
Sumner & Goodwin Co., by F. D. Sumner.
Union Water Meter Company, by J. P. K. Otis and Mr. Northrop.
Wood, R. D. & Co., by Jesse Garrett.

Guests.

William W. Wade, Woburn, Mass.; Mr. Doyle, Wakefield, Mass.; J. F. Monehan, Lowell, Mass.; H. L. Thomas, Hingham, Mass.; and J. W. Milne. Fall River, Mass.

The Secretary read the names of the following list of applications for membership:

Resident Active.

William W. Wade, Water Registrar, Woburn, Mass.

Francis E. Appleton, Paymaster of Locks and Canals Company, Lowell, Mass.

Frederick S. Hollis, Biologist, Boston Water Works.

Nonresident Active.

Edward Phillips, Chief Engineer, Hydraulic Construction Company, New York.

John Caulfield, Secretary Water Company, St. Paul, Minn.

C. O. Probst, Secretary State Board of Health, Columbus, Ohio.

Francis C. Green, Engineer, New York.

On motion of Mr. Fuller, the Secretary was instructed to cast the ballot of the Association for the candidates, and they were declared elected members of this Association.

Lucian A. Taylor read a paper entitled, "Construction of the Water Works, at Newport, N. H." Messrs. Haskell, Fuller, Holden, Walker, Cook, Coffin and Metcalf took part in the discussion.

Frederick W. Gow, Superintendent, Medford, Mass., described the placing of a 10-inch high service main across the Mystic River. The discussion which followed was participated in by Mr. Bates, Mr. Kimball, Mr. L. A. Taylor, Mr. Walker, Mr. Haskell, Mr. Hyde, Mr. Hammatt, Mr. Cook, Mr. Fuller, Mr. Hastings, Mr. Cotton, Mr. Maxey, Mr. Gilbert and Mr. Stacey.

Mr. E. A. W. Hammatt, of Boston, read a paper on "Back Filling Trenches." The subject was discussed by Messrs. Hyde, Haskell, Winslow, Gilbert, Fuller, Fairbanks and Taylor.

Adjourned.

ADJOURNED MEETING.

Young's Hotel,
Boston, Jan. 12, 1898.

President Kent in the chair.

The following members and guests were present:

Active Members.

Solon M. Allis, Francis E. Appleton, Charles H. Baldwin, Lewis M. Bancroft, George E. Batchelder, Oren B. Bates, Joseph E. Beals, James F. Bigelow, John T. Cavanagh, George F. Chace, Charles E. Chandler, G. L. Chapin, Harry W. Clark, William F. Codd, Freeman C. Coffin, H. W. Conant, Byron I. Cook, Henry A. Cook, Eben R. Dyer, Charles H. Eglee, George E. Evans, J. H. Fairbanks, F. F. Forbes, Frank L. Fuller, D. H. Gilderson, Albert S. Glover, W. J. Goldthwait, Frederick W. Gow, E. H. Gowing, Francis C. Green, Frank E. Hall, E. A. W. Hammatt, John C. Haskell, L. M. Hastings, V. C. Hastings, William E. Hawks, T. G. Hazard, Jr., James H. Higgins, Frank W. Hodgdon, Horace G. Holden, Willard Kent, George A. Kimball, Wilbur F. Learned, James W. Locke, Thomas Naylor, Edward Phillips, C. A. Probst, W. H. Richards, George J. Ries, Henry W. Rogers, George A. Stacy, F. A. Snow, Edwin A. Taylor, L. A. Taylor, William H. Thomas, D. N. Tower, Charles K. Walker, William W. Wade, John C. Whitney, George E. Winslow.

Associate Members.

Chapman Valve Manufacturing Company, by E. L. Ross.
Coffin Valve Company, by Mr. Weston.
Deane Steam Pump Company, by F. H. Hayes and C. P. Deane.
Drummond, M. J., New York City, N. Y., by Wm. V. Briggs.
Garlock Packing Company, by Mr. Perkins.
Hersey Manufacturing Company, by Albert S. Glover.
Jenks, Henry F., Pawtucket, R. I.
National Meter Company, by Mr. Lufkin.
Neptune Meter Company, by H. H. Kin
Perrin, Seamans & Company, by H. L. Bond.
Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.
Ross Valve Company, by E. L. Ross and S. R. Stanley.
Smith Benjamin C., New York City, N. Y.
Sumner & Goodwin Company, by F. D. Sumner.
Thomson Meter Company, by S. D. Higley.
Union Water Meter Company, by J. P. K. Otis.
Wood, R. D. & Company, by Jesse Garrett.

GUESTS.

W. E. Hassam. C. E., Worcester, Mass.; A. A. Blossom, Salem, Mass.; J. F. Gleason, Quincy, Mass.; John Gardner, Taunton, Mass.; H. Phipps, Boston, Mass.; J. Taylor, Weymouth, Mass.; H. L. Thomas, Lowell, Mass., and J. S. Beal, Lowell, Mass.

Henry L. Davis, Superintendent of Water Works, Wallingford, Conn., was elected a resident active member, and George A. Soper, Civil Engineer, now connected with the Western Division of the Boston Water Works, was elected a nonresident active member.

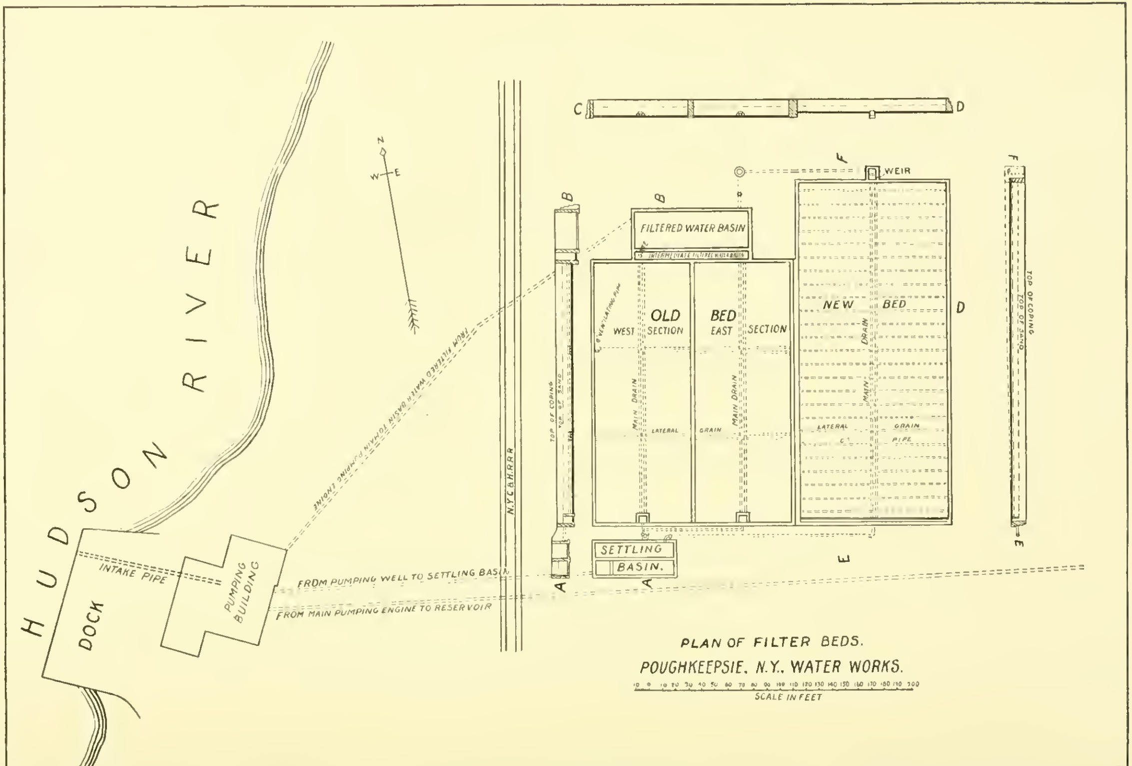
On motion of Mr. Fuller the thanks of the Association were extended to Mr. Forbes for his courtesies extended to the members of the Association on their visit to the new Brookline public bath.

Mr. W. E. Hassam read a paper giving a description of the Worcester distributing reservoir.

Mr. E. H. Gowing read a paper entitled "Back Filling Trenches from Another Standpoint." The paper was discussed by Messrs. Fuller, Beals, Hammatt, Chace, L. Taylor, E. A. Taylor, Haskell, Richards, Hazard, Eglee and Evans.

Mr. D. N. Tower, Superintendent of the Cohasset Works, read a paper on "Handling Air in a Tube Well Pumping Plant."

Adjourned.



PLAN OF FILTER BEDS.

POUGHKEEPSIE, N.Y., WATER WORKS.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XII. June, 1898. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE OPERATION OF A SLOW SAND FILTER.

BY CHARLES E. FOWLER, SUPERINTENDENT AND ENGINEER OF PUBLIC WORKS, POUGHKEEPSIE, N. Y.

[*Read March 9, 1898.*]

Mr. President and Members of the New England Water Works Association: Having been honored with a request to present before you a paper on the "Operation of a Sand Filter" I will endeavor to comply by narrating some of the experiences met in the effort, during the past seventeen years, to render the water of a sewage polluted river fit for domestic use by means of such an appliance.

The sand filter of my experience is located at Poughkeepsie, N. Y., a city of about 23,000 inhabitants, situated on the east bank of the Hudson River, about midway between its mouth and the head of navigation.

The construction of its system of water works was commenced in 1869 and completed in 1872. The commission entrusted with the work investigated every probable source of supply and arrived at the conclusion, which subsequent years have fully justified, that the Hudson River afforded the only assurance of an ample volume within the limits of reasonable cost. Their consulting engineer was the late James P. Kirkwood, of Brooklyn, N. Y., who had but recently investigated the filtration systems of Europe in the interest of the city of St. Louis, Mo. The city of St. Louis did not adopt the filtration system, but it was applied to the water supply of Poughkeepsie under Mr. Kirkwood's supervision and in accordance with his plans.

The Hudson River, at Poughkeepsie, has a drainage area of about 11,500 square miles. Within this area is a total population of about 1,000,000 and an urban population of about 500,000. Fifteen miles above Poughkeepsie, on the west shore, is the city of Kingston containing about 23,000 inhabitants. Forty miles above, on the east shore, is the city of Hudson, containing about 10,000 inhabitants. Seventy miles above, on the west shore, is the city of Albany with about 96,000 inhabitants and, above Albany, a total urban population of about 300,000. A short distance above Poughkeepsie, on the same side of the river, is located one of the New York State Hospitals for the Insane. The patients and attendants make a population of about 1,500 or upwards. The institution is completely sewered and the outfall is in the Hudson River 2,797 feet above the intake of the Poughkeepsie water works. The ebb tidal currents flow directly from this outfall past the intake. The central sewer outfall of the Poughkeepsie system discharges into the river 6,124 feet south of the water works intake, and the flood tidal currents, from the outfall, pass far above the intake but nearer the center of the river. The width of the river at the water works intake is about 2,400 feet with a nearly uniform depth of 50 feet, the shores being quite bold.

The pumping plant is located at the edge of the river. The filtration plant, as originally constructed, is located about 500 feet easterly and about 28 feet above mean high water in the river. This plant consists of a settling basin 25 feet by 60 feet in plan and 12 feet deep. The bed is 200 feet long by 150 feet wide, divided longitudinally into two sections by a wall in the center. The walls are vertical, of rubble masonry, and 12 feet in height from coping to top of concrete bottom.

The filtering materials occupy one half the depth, comprising, beginning at the bottom, 24 inches of coarse broken stones, 6 inches two-inch gravel, 6 inches one-inch gravel, 6 inches one-half-inch gravel, 6 inches one-quarter-inch gravel and 24 inches of sand. A main drain, of dry rubble 2 feet by 2 feet in cross section, extends longitudinally through the center of each section and two lateral drains of same dimensions traverse each section at right angles to the main drain.

A gate is placed at the outlet of each main drain, opening into an intermediate chamber 6 feet wide by 88 feet long and 16 feet deep,

from which the filtered water passes, over a weir, into a filtered water basin 88 feet long by 28 feet wide and 17 feet deep. From this basin the filtered water passes to the main pumping engine and thence to the distributing reservoir.

The distributing reservoir has a capacity of 12,000,000 gallons or a practical maximum supply of seven days.

The filter bed was put in operation in 1872. In 1874 an attempt was made to substitute subsidence in the distributing reservoir for filtration and the annual report for that year states that "The use of these beds has been abandoned except as may be occasionally required, when from the stage of the river the water may be unusually turbid." In the year 1875 the bed was in use about six months. In the year 1876 the annual report states they "Were in almost constant use." In the report for 1877 it is stated "The entire supply for this year was filtered." In the report for 1878 the volume filtered is the entire volume pumped, and it is added "The consumers accustomed to drink filtered water will accept nothing else, nor will they consider any circumstance, or complication of circumstances as offering any excuse for their nonuse." In the report for 1879 and 1880 the volumes filtered are the entire volumes pumped. The attempt to abandon the filter bed was not successful.

When I assumed charge of the works, in January, 1881, I found the bed not in use owing to a heavy coating of ice which rendered cleaning difficult. I at once caused the ice to be removed and the bed cleaned and put in operation. From that day I have not at any time seen the water of the river, judging from appearance alone, in fit condition for domestic use without some effort at purification. At that time bacteriological examinations of water supplies were unknown and but few chemical examinations had been made of the Poughkeepsie water; nevertheless I was impressed with the belief that that filter bed, in its best possible condition, was essential to the satisfactory quality of the water supplied to the city and upon that principle have based all action relative thereto, and have allowed no water to be supplied to the city without passing through it.

From various causes the river water has been much more heavily charged with mud and silt at all seasons, during the past eight or ten years, than previously. The normal rate of filtration, that is,

the water pumped from the clear water basin, prior to 1893, was 4,500,000 gallons per acre per twenty-four hours. Since 1893 the rate has been 5,000,000 gallons, or over, per twenty-four hours, per acre. The head, or difference of level between the surface of the water on the bed and that in the intermediate filtered water chamber, required to obtain this rate varied according to conditions, from 1 foot to 6 feet and, in extreme cases, it has increased to 7 feet or even 8 feet or more. During the last six or eight years the endeavor has been to make 4 feet the maximum.

The word "conditions" has a very broad significance to one who has been obliged to meet them. To understand this it must be borne in mind that there was on the one hand, among the consumers of water, a lingering impression, occasionally expressed, that the filter was not in use, and, on the other hand, my firm conviction that the constant use of the filter was a sanitary necessity and a firm determination that no unfiltered water should be pumped to the city.

A feature of this bed was a set of six 6-inch cast iron pipes. in each section, one being set vertically over each end of the main drain and the outer end of each lateral. They were open at each end and extended from the top of the drain nearly to the top of the side walls. The purpose of these pipes, evidently, was to provide an exit for the air in the lower portion of the bed when it was being filled by water flowing on the top and thereby prevent disturbance of the sand. I discovered after a time, however, that a practical use was made of them not altogether intended by the designer. I noticed that after reaching nearly the limit of head the bed would sometimes seem to run for a disproportionate time without material increase.

Upon examination and inquiry I found that the night engineer, and not infrequently the day engineer, would, in order to delay the cleaning of the bed, allow the water to rise and overflow these ventilators thus admitting an appreciable volume of unfiltered water to the drains below and relieving the bed. This practice was prohibited at once and a close watch maintained to prevent its recurrence.

During the years 1881 to 1883 the water of the river was much clearer than I have seen it since and, consequently, the work of the bed was less. It was the practice to "clean" the bed by removing from the surface of the sand the silt left by the water in passing

through. This was done whenever the bed failed to pass enough water under the given limit of head. The work was done by men with square pointed shovels who "skimmed" the slimy coat from the sand and deposited it in wheelbarrows which were wheeled by other men and deposited at the side of the bed. Still other men threw the deposit to the bank above. When the bed was new this was sufficient, but when I assumed charge it was not sufficient and it was the practice, after skimming, to loosen the sand with garden forks and then rake the surface over. This would not be done at every cleaning, but it soon became necessary to do it at every cleaning; and, after a time, even this was insufficient to enable the water to pass through readily but it would require from twelve hours to forty-eight hours after cleaning, for the bed to deliver the normal rate. In the construction of this bed no provision was made for drawing the water from above the surface of the sand when it became necessary to clean it. It was necessary, therefore, for the water to filter through before the work of cleaning could be commenced. In 1885 the condition of the filtering material had become such that forty-eight hours were required, after pumping ceased, to drain the sand so that cleaning could begin.

Prior to this time it had been the practice to replace the sand on the bed when a depth of about 6 inches had been removed in cleaning. Once only a depth of 10 inches had been removed. Below this depth the filtering material had not been disturbed since construction. Under the conditions mentioned it will be observed that a period of five days would be required from the time pumping on the bed ceased, in order to prepare for cleaning, to the time of obtaining normal flow from the bed after cleaning, namely, two days for draining, one day for cleaning and two days for obtaining normal flow.

At such a time if a storm, lasting two or three days, should occur to prevent cleaning the effect will be readily understood.

On the fourth day of January, 1886, a severe storm occurred as the bed was being cleaned and stopped the work when about two-thirds done. The rain was succeded by a muddy state of the river water previously unknown. In addition to this a period of severe cold set in which caused a large increase of consumption amounting in some days to nine-tenths of the full capacity of the pumping engine. The bed was filled to the coping and forced to its utmost,

but was unable to filter the full amount of daily consumption and the balance overflowed through the ventilating pipes, before mentioned, unfiltered, rendering the water delivered to the city very roily and causing great complaint. By constant pumping it required nearly three weeks to store sufficient water in the reservoir to permit the pumps to stop long enough to clean the bed and, when it was again cleaned its efficiency was but little improved. The sand pores had become so filled as to render it, under the water pressure necessary, like a mass of compact loam and almost as impervious to water. It thus became necessary, at once, either to remove the sand entirely and replace it with new, or after removing the old sand to wash and replace it. The latter course was decided upon and, accordingly, the entire body of sand was removed, to the gravel, and washed and replaced. The work was commenced in the latter part of March and completed the latter part of October, the bed being in continuous use meanwhile. A thickness of from 1 inch to 2 inches of sand was removed at a time and washed and placed in a pile. Then another, equal thickness, and so on. When the sand had been removed to within about 3 inches of the gravel the east section of the bed was shut off, the remainder of the sand removed from it, and washed, and the full depth of the washed sand replaced on this section.

During this time all the water pumped to the city was filtered through the west section. The west section was then shut off and the process repeated there. When the work of replacing was completed on both sections the bed was, apparently, in as good condition as a new bed. From this time the sand removed in cleaning, and washed, was not replaced as frequently as heretofore.

No sand was replaced until 1890 when, the sand remaining on the bed, about 6 inches in depth, was removed and washed and all was replaced as before. In 1893 the sand removed and washed during the previous three years was replaced on the bed together with about 400 cubic yards of new sand. In 1894 about 300 cubic yards of new sand was added and about the same quantity of old sand replaced making a depth of about 7 inches. In 1897 all of the sand on the bed was removed and wasted and new sand to the depth of 30 inches put on the bed.

One of the worst experiences occurred during the month of April, 1895. A heavy rain, on the 8th and 9th, brought down a charge of red mud and silt which stopped filtration. The pumps

were stopped on Thursday morning, the 11th, with nearly 14 feet of water in the reservoir. Allowing forty-eight hours for draining the bed we expected to clean on Saturday. On Saturday, however, it rained heavily; also a part of Sunday, so that no cleaning could be done until Monday, the 15th; but, even then, the bed was not sufficiently drained, owing to the rains of Saturday and Sunday. A force of men was put on and urged to their utmost and the bed cleaned and pumping to the reservoir started at seven o'clock in the evening, with less than 4 feet in the reservoir. Since it is impracticable to draw from the reservoir below 3 feet we had but 1 foot available, or twelve hours supply, when pumping began. The river being still very muddy we were compelled to stop pumping on Saturday morning, the 20th, after running four and one-half days. The bed was cleaned on Monday, the 22nd, and pumping began with less than 3 feet available in the reservoir. We were again obliged to stop on Saturday morning, the 27th, after running four and one-half days and clean on Monday, the 29th, starting the pumps with less than 3 feet available in the reservoir, so that three times during that month, we were in such condition that a rain storm of twenty-four hours would have compelled us to pump unfiltered water. We were obliged to clean the bed again on the 6th of May, making four times in five successive weeks, an experience unequaled before or since.

One of the great hindrances to the operation of this bed has been the growth of a species of green, filamentous, algæ on the surface of the sand. It does not develop in every year nor at the same time in the year. It sometimes begins in the latter part of May and sometimes not until September. It usually disappears with heavy frost. Its development begins in small round patches on the surface of the sand and continues with greater or less rapidity, according to temperature and condition of the water, until the entire surface is covered as with a blanket and the passage of water is entirely stopped. It has been known to develop on the clean sand and entirely stop filtration within seven days from cleaning. An essential condition for its rapid growth is clear sunlight. It will not develop in the dark and very little in the shadow of any object. All the basins, as constructed, were open to the sunlight. Much trouble was experienced from the growth of the same species of algæ in the clear water basin. In 1891 this basin was covered so as to exclude the light and no trace of algæ has been seen in it since. When filtration

is stopped from this cause there is no alternative but to drain the bed and clean in the usual way. The algæ cannot be removed under water. When the bed is drained and the algæ is allowed to dry it will cohere and roll up like a piece of paper. But touched with a shovel or other appliance for its removal, under water, it instantly flies in all directions in minute particles which immediately settle upon the sand and commence development vigorously on their own account. It has sometimes happened that the delivery of the bed has commenced to decrease, from algæ growth, within forty-eight hours after its removal. These extreme cases are, however, of rare occurrence. As this development always occurs during one of the seasons of greatest consumption of water it has sometimes taxed us to the utmost to maintain the supply of filtered water. I have never observed that its presence imparted either odor or taste to the filtered water.

During the last eight or ten years the frosts of winter have greatly hindered the maintenance of the bed in proper working condition. As before mentioned the river water has been much more turbid during this later period and it has seemed much more difficult to catch a thaw at the right time, and of sufficient duration, to enable the bed to be properly cleaned. In order to clean in the winter the first operation is to remove the ice. This will vary from 10 to 20 inches in thickness and we have removed some 28 inches thick, though that thickness is very seldom attained and then does not extend over the entire surface. In removing the ice the bed is filled to the coping, and the ice cut in pieces and hauled out by men. The operation requires about a week, more or less, depending upon the thickness of ice and the number of men employed. When the ice has been removed, pumping is stopped and the bed drained. If we have struck a favorable thaw, and, if during the forty-eight hours or more required to drain the bed no frost occurs and none occurs until the bed is cleaned, all is well and the bed will probably be in good order. It, however, more frequently occurs that 2 or 3 inches of ice forms while the bed is being drained.

We have sometimes removed the ice and drained the bed without frost, and early in the morning of the day of cleaning, a sudden drop in temperature occur that would freeze the sand and stop the work before it was completed. It sometimes happens that we are unable to foresee the failure of the bed in time to remove the ice owing to a sudden change in the character of the river water. In

such cases an effort is made to clean by lowering the ice on the sand, breaking it up, turning over the pieces and cleaning underneath. This is very unsatisfactory and only undertaken in emergencies. A sudden drop of temperature will sometimes stop even this operation before it is completed. In February, 1893, the bed suddenly failed with about 10 or 12 inches of ice on the surface and low water in the reservoir. It was impossible to continue and the bed was drained and the ice lowered to the sand. As much ice as possible was removed from one section while the bed was being drained. The work of cleaning was commenced, but before two-thirds of the section from which the ice had been removed, had been cleaned, the sand froze to such an extent that the work was stopped. There were but 5 feet of water in the reservoir and I decided to turn on the water and get what we could from the bed, fully expecting to be compelled to pump direct from the river within the next twenty-four hours. To my surprise, on going to the bed the next morning, I found it delivering its normal flow. The ice, on the section from which none had been removed, had settled evenly upon the sand and the severe cold had frozen the sand to the under side so that when the ice arose with the inflowing water it carried about one inch of sand from the entire surface of that section with it. It is not a method of cleaning to be recommended but it delivered us at the only time in my experience that the elements were in complete mastery. It is very rare, however, that all the conditions would be favorable to such action.

The under surface of the ice must be even, the surface of the sand even, the thickness of the ice sufficient to lift the sand and not enough to protect the sand from cold and the cold intense enough to freeze the sand under the ice. All of these conditions must occur together, which is very seldom the case.

In cleaning the bed, as before described, from one-quarter inch to one-half inch of sand was removed under normal conditions. In cases of frost the depth would be increased, sometimes to 2 inches or more. The labor required, under normal conditions, was one man for each 150 square feet of surface cleaned per hour, including wheeling and elevating to bank. As the sand is in use it becomes, in time, coated with a gelatinous film, throughout its depth. The finer silt also extends, in continually decreasing quantity, for a considerable depth below that removed by cleaning. The pressure to maintain a given flow, with the surface clean, gradually in

creases. Consequently, the pressure throughout increases, until, after a sufficient time, the water will not pass through even after cleaning and it becomes necessary to loosen the sand. This is done by the use of garden forks, as before mentioned, which are pressed into the sand a sufficient depth, vertically, and the top of the handle drawn backward sufficiently to loosen the sand in front of it.

At first the forks need enter but 3 or 4 inches but the necessary depth gradually increases until the full length of the fork is used and even this is not sufficient and the entire body of sand must be removed and washed or renewed as was the case in 1886. After the sand is loosened the surface is raked over evenly with a garden rake. Forking and raking requires about one man to each 500 square feet of surface per hour.

Under the foregoing conditions of sand and pressure, the sand will sometimes become so compact and hard that a considerable force is required to press the fork into it, and the tramping of men on the surface makes no impression. The time required for a filter to attain the condition referred to as occurring in 1886 would, of course, depend upon the rate of filtration and the character of the applied water. The period of constant use had been about ten years previous to 1886. Subsequent to that the sand was all removed and replaced at the end of four years, in 1890, before such condition had attained. Subsequent to that the entire body was not removed until 1897, a period of seven years, when the same conditions occurred and it would have been impossible to complete the year. The most favorable conditions for cleaning are fair, mild weather, not cold or hot, with the sand slightly moist. In the heat of summer, under a glaring sun, the sand sometimes becomes baked to a depth of nearly an inch compelling the removal of a depth greater than would be necessary, were this not the case, thus increasing the expense. Greater care is required in cleaning as the bed grows older. The shovels should be lifted on the return stroke and not drawn backward on the sand, particularly, if the sand is moist. When the bed is to be forked and raked this is not essential. When the bed is new the only effect of a shower of rain, during cleaning, is to delay the work while the shower lasts, but if the bed has become clogged to any extent, even if it has not been necessary to loosen with forks, a heavy shower will so compact the surface as to necessitate recleaning the portion that has been cleaned or loosening it with rakes. If heavy rain falls upon a por-

tion that has been forked and raked it will be necessary to repeat both the forking and raking before the delivery will be satisfactory. The effect of a fall of snow, during cleaning, is to increase the labor and expense and, if the snow is moist or melting, and the sand at all clogged, will require the removal of a greater thickness of sand.

In 1886 two bridges were constructed, one spanning each section of the bed. These bridges were movable, laterally, lengthwise of the bed, upon rails laid upon the coping. From the bridges platforms were suspended a little above the surface of the sand. In cleaning the men stood upon the platforms, scraped the surface of the sand and deposited the scrapings upon the platforms.

When about one-third of the bed had been cleaned the bridge, with its load, was moved to one end of the bed and the load thrown upon the bank. By this method there was no wheeling or tramping, whatever, upon the sand. One man, by this process, would clean 240 square feet of surface per hour, under normal conditions. For two or more years all the cleaning was done by two men. One section of the bed being used while the other was being cleaned.

The two men would clean one section in three days. This method was abandoned chiefly because it was impracticable to so regulate the draft upon the section in use as to avoid overworking it and hastening its clogging. There was a material saving in cost of cleaning by the use of these bridges, but in the construction of the new bed, in 1896, owing to the increased cost of construction necessary for their use, this feature was omitted. In 1897, the timber work of the bridges having decayed to such an extent as to require renewal, their use was discontinued for the sake of uniformity of operation and a better appearance of the plant.

We have now returned to the original method of cleaning.

Several methods have been used for washing sand. The one in use when I assumed charge was to cause the sand to pass over two inclined troughs, each about 12 feet long.

Near the upper end of the first trough the sand was met by small streams of water issuing from a perforated pipe under a pressure of about 100 pounds per square inch. The inclination of the troughs was such that the water carried the sand down and the force of the small jets, with the attrition of the particles during the flow, separated the silt from the sand. The water and sand were discharged into a box or tank, the sand settling to the bottom and the water

flowing off at the top carrying the silt with it. Between the lower end of the upper trough and the upper end of the lower one, was a screen through which all the sand passed on its way down. Four men were employed who washed less than 3 cubic yards per day at an average cost of about $2.38 per cubic yard. The washing was very efficient. This system was changed by increasing the number of troughs and dispensing with the services of two men thereby reducing the cost to about $1.47 per cubic yard. The work was carried on from April to December. In 1886 a trough 240 feet long was constructed and an additional supply of water taken from the settling basin. Five or six men were employed and about 2,000 cubic yards washed from March to September, at a cost of about 61 cents per cubic yard.

This method was continued, with a less number of men, depending upon the quantity to be washed, for several years. The work done by this arrangement was not altogether satisfactory, and, in 1892, a machine was put in operation consisting of a circular tank in which was a vertical, hollow shaft with perforated arms projecting horizontally from the bottom. This shaft was made to revolve slowly by means of a water motor, the water from which passed down through the hollow shaft and out through the perforated arms. The sand was placed in the tank and agitated by the revolving arms while the water flowed up through the sand and off at the top of the tank carrying away the sand and silt. The sand, when sufficiently washed, was discharged through a valve at the bottom of the tank. The work done by this machine was very satisfactory except that it was difficult to separate the leaves and algæ, particularly the latter. The cost, by this method, was about 64 cents per cubic yard. In 1895 and 1896 a single jet washer was used. By this plan the cost was reduced to about 54 cents per cubic yard. For several years the work has been done mainly by two regular employees, together with other work, and the quantity washed in a given time, with a given quantity of water, would depend upon the diligence of the men. The figures given are for ordinary work. In November, 1897, in washing and replacing the sand removed from the new bed, since it was put in operation in December, 1896, a double jet of much greater capacity was used. The sand and water from the first jet was discharged into a tank from which the water and silt flowed off at the top while the sand passed through a valve in the bottom into the second jet. From this jet the water and sand were transported

about 130 feet to a tank over one corner of the bed. The water and remaining silt flowed off from the top of this tank and the sand discharged through a valve in the bottom on the bed.

A little over five cubic yards of sand were washed and delivered on the bed, per hour, by this means. The total cost of labor at eighteen cents per hour, for washing and delivering on the bed, was 24 cents per cubic yard. Cost of water three cents per cubic yard. Total 27 cents per cubic yard. The quantity of water used was eighteen times the quantity of sand. The work was well done.

The water used was filtered water taken from the force main.

The total quantity of sand washed was 325 cubic yards. The number of hours worked was sixty.

No examinations, chemical or otherwise, for the determination of the efficiency of the bed, were made for several years after its construction. In November, 1877, an analysis was made by the late Prof. W. R. Nichols of the Massachusetts Institute of Technology. Twelve years later, in November, 1889, an analysis was made by Dr. T. M. Drown, then of the above mentioned institute; also one in 1891. The results of these three analyses, in parts per 100,000 of albuminoid ammonia, before and after filtration, also the percentage of reduction of albuminoid ammonia, of free ammonia and total solids, are as follows:

Date.	Albuminoid Ammonia. Parts in 100,000. Unfiltered Water.	Filtered Water.	Percentage of Reduction. Alb. Am.	Free Am.	Tot. Sol.
November, 1877	.0197	.0139	29	30	24
November, 1889	.0198	.0130	34	68	22
November, 1891	.0153	.0100	35	100	28

During the fourteen years from November, 1877, to November, 1891, the materials composing the bed had not been disturbed except by washing and replacing the sand. No new sand had been added. These analyses show no deterioration in efficiency, but rather, a material increase, during that period.

The results of a series of six analyses, made by Dr. Drown in June, 1893, showed a percentage of reduction by filtration, as follows:

Albuminoid ammonia	38.2	per cent.
Free ammonia	97.	"
Nitrogen, as nitrites	96.	"
Oxygen consumed	29.	"
Nitrogen, as nitrates (increased)	40.	"

Ordinarily, little or no effect is produced upon the color of the river water by passing through this filter, though one analysis by Dr. Drown, showed a reduction of discoloration as great as 60 per cent as the result of filtration.

Bacteriological examinations, three in number, made by Dr. Drown in November and December, 1891, showed percentages of removal, highest 97.7 per cent, lowest 92.4 per cent, average 94.9 per cent. An examination by Dr. Drown in January, 1892, showed percentage of removal 82.1 per cent; and in December, 1892, 91.8 per cent.

In 1895 eight bacteriological examinations were made by D. B. Ward, M. D., of Poughkeepsie, from April to December, showing an average removal of 93.8 per cent, with maximum of 98.6 per cent in June and minimum of 85.9 per cent in October. On February 14, 1896, an examination by Dr. Ward showed only 31 per cent removed; and in February 24th, but 37 per cent removed.

The death rate from typhoid fever has varied materially during the past 18 years, as will appear from the following table showing the population, in each year, from 1880 to 1897, both inclusive, as estimated from the ratio of increase in the census returns of 1890 over those of 1880, together with the number of deaths, from that cause in each year, and the number per 10,000:

Year.	Estimated Population.	No. of Deaths from Typhoid Fever.	No. of Deaths per 10,000.
1880	20,200	12	5.9
1881	20,400	10	4.9
1882	20,600	22	10.6
1883	20,800	9	4.3
1884	21,000	11	5.2
1885	21,200	11	5.1
1886	21,400	4	1.8
1887	21,600	5	2.3
1888	21,800	5	2.2
1889	22,000	6	2.7
1890	22,200	6	2.7
1891	22,400	9	4.
1892	22,600	13	5.7
1893	22,800	22	9.6
1894	23,000	15	6.5
1895	23,200	10	4.8
1896	23,100	5	2.1
1897	23,600	11	4.6
			Average. 4.72

There appears to be no definite relation between the condition of the filter bed and the death rate from typhoid fever, except that the greatest number of deaths, from this cause, occur from January to April, when the efficiency of the bed is the lowest. In 1886 the condition of the bed was, certainly, the worst of any year of the eighteen under consideration, yet, the rate, 1.8 per 10,000, was the lowest of any year in that period. It is probable that the bed was not in as good order in February, 1893, when the rate was 9.6 per 10,000, as in 1892 or 1894, when the rate was much lower; it was certainly, however, in no better condition in 1886 than in 1892 and 1894. Of course the want of frequent bacteriological examinations deprives us of accurate knowledge, but these are the facts so far as they can be known without them. During the last six or eight years a higher rate of filtration has prevailed owing to increased leakage in the filter basin and the introduction of a pumping engine of greater capacity.

In 1896 an additional filter bed was constructed having an area equal to the old bed, thus doubling the filtering area. This bed consists of a single basin having a length, inside of walls, of 260 feet and width of 114 feet. Total area 29,640 square feet. The clear depth of the basin from the top of the coping to the surface of the concrete bottom, is 10.3 feet. This bed adjoins the old bed on the east and the side walls consist of rubble masonry laid in Rosendale cement mortar, faced with a brick wall laid in Portland cement mortar. The inner faces of the walls are vertical. The bottom is of concrete.

A main drain, of brick masonry, sunken below the surface of the concrete, extends longitudinally through the center of the basin. Lateral drains of 6-inch tile pipes are laid on the concrete bottom at right angles to the main drain, and 10 feet and 3 inches apart between centers. These lateral drains are covered with 2-inch broken stone. The spaces between the laterals are filled, to a depth of 10 inches, with 2-inch broken stone and 1-inch gravel. Above this is a layer of one-half inch gravel 8 inches thick, and above this, a layer of one-quarter inch gravel 6 inches thick; the total thickness of the gravel layers being 24 inches. Above the gravel is the filtering sand 31 inches in thickness. The water for this bed is taken from the settling basin of the old bed. The main drain discharges into a delivery well, 6 feet by 8 feet, on the out-

side of the north wall of the basin. In this well is a weir of cast iron, sliding in vertical grooves, by means of which the working head may be regulated. From this well the filtered water is conducted to the filtered water basin of the old bed.

The supply and delivery are controlled by gates so that the bed may be cut off at will. The sand and gravel, for this bed, were obtained from a bank at Hempstead Harbor, on Long Island.

They were screened and washed at the bank and delivered along side. our dock on scows from which they were delivered to the bed by carts. Water was let on this bed on December 17th, 1896. From the beginning of 1897, nearly all the work devolved upon this bed owing to the clogging of the old one.

About the first of June, 1897, the old bed was shut off and the work of repair commenced. The sand remaining thereon was entirely removed and wasted. The gravel and broken stones, forming the lower portion of the bed, originally 4 feet in depth, was excavated around the outer wall, to the bottom, of sufficient width to permit working. The joints of the rubble masonry composing the side walls were cut out and filled with mortar composed of Trinidad asphalt and sand, applied hot and driven in with hammers. A trench about 3 inches wide and 4 inches deep was cut in the concrete bottom, next the wall, which was filled with the same mortar rammed solid. The surface of this trench, and the bottom for about 2 feet from the side walls, also the side walls, were covered with a thin coat of melted asphalt.

Rainy weather in July and August greatly hindered the work, not only by loss of time during the storms but by the time required, after the storms, to render the joints sufficiently dry to receive the asphalt mortar. This was, in large measure, overcome by the use of pulverized quick lime, which absorbed the moisture and imparted sufficient warmth to the joint to enable the mortar to adhere. After the side walls were completed the broken stones and gravel were replaced. New sand was then placed on the entire bed to the depth of 2½ feet. It was found that the stones and gravel had settled about 6 inches.

The different grades of gravel had become mixed to a considerable extent. Sand was found among the broken stones at the bottom.

Whether this intermingling was due to carelessness in the or-

iginal placing of the materials or to the operation of the bed is not known.

The sand placed on the new bed, before described, although screened and washed at the bank, still contained a sufficient quantity of loam to impart turbidity to the filtered water, in greater or less degree, for nearly six months after it was put in service. The new sand placed on the old bed came from the same bank and was screened and washed in the same manner. In order to avoid the difficulty experienced with the new bed the sand was transported from the scow to the bed by means of a hydraulic jet. An ejector was so placed at the dock as to reach the center of the scows and to raise and lower with the tide.

The ejector was supplied with water from the force main at the engine house. A line of 4-inch cast iron pipe extended from the ejector to the top of a tank on the division wall at the center of the old bed. The sand was shoveled into a hopper attached to the ejector on the scow and the water and sand delivered into the tank on the wall. The water, carrying with it the loam and silt, flowed off from the top of the tank and the sand was discharged, through a valve in the bottom, on the bed, perfectly clean, having been thoroughly rinsed in the transfer. The length of the 4-inch pipe, from the ejector to the tank, was 630 feet. Total lift, from scow to top of tank, 30 feet. Diameter of jet 1 inch. Diameter of nozzle $1\frac{1}{2}$ inches. Water pressure at jet about 110 pounds per square inch. Quantity of sand discharged 8 cubic yards per hour. This bed was put in service about the first of October, 1897, and its operation has been most satisfactory from the first.

The sand used in the original construction of the old bed was in two grades, the coarser having been obtained on the bank of the Hudson river at Roa Hook, about 30 miles south of Poughkeepsie. The finer was obtained in New Jersey. In the years of use these two grades have become intermingled somewhat with each other, and with additional sand purchased.

The following table shows approximately the mean diameters of the grains of sand comprising:

First, the lower portion of the old bed, which was removed in 1897.

Second, the upper portion of the old bed, which had been previously removed.

Third, the new sand placed on the old bed in 1897.

Fourth, the sand used in constructing the new bed in 1896.

	1 m. m. and above. Per cent.	.5 m. m. to 1 m. m. Per cent.	.25 m. m. to .5 m. m. Per cent.	.05 m. m. to .25 m. m. Per cent.
Old sand removed from old bed in 1897	37	19	41	3
Sand from upper portion of old bed	12	13	53	22
Sand placed on old bed in 1897	25	19	50	6
Sand used in new bed in 1896	24	18	44	14

The old sand removed in 1897 was considerably worn, the grains apparently rounded by the sharp corners having been broken off.

The difference in size between the sand placed on the old bed in 1897 and that used in the new bed in 1896, is due to the washing of the former which removed a considerable portion of the finer sand. The coarser grade of the old sand was very irregular in size; some grains being 6 m. m. or 8 m. m. in diameter, showing that gravel had become mixed with it. The coarser grade of the other sands was quite uniform.

Since December, 1897, both beds have been in operation. Six bacteriological examinations have been made by Dr. Ward of Poughkeepsie showing the following results :

Date.	Source of Water.	Colonies per cubic c. m.	Per cent. removed.
Dec. 23, 1897	Settling basin,	14,160	
"	Effluent, old bed,	166	98.8
"	" new bed,	872	93.
Jan. 6, 1898	Settling basin,	17,850	
"	Effluent, old bed,	132	99.26
"	" new bed,	348	98.02
Jan. 19, 1898	Settling basin,	27,000	
"	Effluent, old bed,	480	98.2
"	" new bed,	900	96.6
Jan. 27, 1898.	Settling basin,	17,850	
"	Effluent, old bed,	52	99.70
"	" new bed,	60	99.66
Feb. 4, 1898	Settling basin,	13,950	
"	Effluent, old bed,	144	98.96
"	" new bed,	88	99.36
Feb. 24, 1898	Settling basin,	19,600	
"	Effluent, old basin,	690	96.47
"	" new basin,	298	98.47

Average old, 98.56 per cent; average new, 97.52 per cent; average all, 98.04 per cent.

The old bed was cleaned on November 13th, and from that date until December 1st, all the water was filtered through it, the river water, meanwhile, being very roily. Since December 1st more water has been drawn from the new bed than from the old. The next cleaning of the old bed was on March 1st, 1898. The new bed has not been cleaned since December 1st, 1897.

The total cost of the original plant, as given in the reports of the department, including land, pumping plant, wells, etc., was $75,-694.82. Deducting the cost of land, pumping engine, pumping well and supply and delivery pipes leaves the cost of the bed proper with settling and clear water basins, about $62,000.00.

The cost of the new bed, exclusive of land, was $28,898.70.

For 20 years, from 1877 to 1896 both inclusive, the total volume filtered, exclusive of leakage, was 11,848,600,000 gallons. The total expenditures, in connection with the bed, during that period, was $35,468.37, which gives for the average cost of maintenance and operation, for a period of 20 years, $2.99 per million gallons.

DISCUSSION.

MR. HAZEN. I think that we are all greatly indebted to Mr. Fowler for his paper and the information which it contains. I was fortunate enough to find out several years ago that Mr. Fowler had a remarkable fund of experience and observation upon the subject which he has treated in his paper, and that he was disposed to give others the benefit of his experience. I am particularly glad that he has been able to present some of this material to the Association, and to put on record facts in regard to the first sand filter plant in America, which will be of the greatest value to all interested in the purification of public water supplies.

Mr. Fowler has been operating sand filters for a much longer period than anyone else in America. He has filtered, I think. a larger amount of water than anyone else in America, and the results that he has gotten are certainly very valuable and instructive to us, and the work of the plant as a whole is very suggestive. Mr. Fowler has labored under numerous difficulties. His filtering area has been at times inadequate; the filters were constructed a long time ago, on filled ground, and unequal settlement has resulted in cracks and in a loss of water and also in the flow of the water from one side to the other, which has seriously interfered with the operation of the plant; but in spite of all these difficulties, he has been supplying filtered water for all these years and with admirable results.

He has given you some statistics as to typhoid fever in Poughkeepsie, but to fully appreciate the significance of those statistics one needs to compare them with the corresponding statistics for other cities up and down the river, which have been using the water without filtration, and these other cities have had rates right along several times as high as Poughkeepsie has had, and when there have been epidemics in these other cities Poughkeepsie has remained pretty nearly free from typhoid fever.

I have a tabular statement of the operation of some sand filter plants giving the amount of water filtered for a year, the areas of the filters, the average rates, the area of filter surface cleaned, and the water filtered per acre between scrapings. It is the data one likes to have when one is figuring on the area of filters to be provided, and the cost of operation.

RECENT FILTER STATISTCS.

Place.	Year ending in	Quantity filtered Million gallons.		Area of filters. Acres.	Av'r'ge daily yield. Million gals. per acre.	Filter area cleaned acres. One year.	Million gallons per acre filtered between scrapings.
		For year	Daily Average				
Altona	Mar. 1896	1,730	4 75	3.08	1.55	48.5	
Amsterdam	Dec. 1894	3,720	10.20	10.37	0.98	139.0	27
Ashland	Feb. 1897	398	1.09	0.50	2.18	4.83	83
Berlin	Mar. 1896	13,000	35.60	25.10	1.42		
Bremen	Mar. 1896	1,220	3.34	3.21	1.04	32.5	38
Breslau	Mar. 1896	2,960	8.10	5.12	1.58	40.0	74
Brunswick	Mar. 1896	840	2.30	1 48	1.56	13.3	63
Copenhagen	Dec. 1895	2,330	6.40	2.88	2.22	44.7	52
Dordrech	Dec. 1894	365	1.00	0.56	1.79		
Frankfort on Oder	Dec. 1895	310	0.85	0.37	2.38	2.9	107
Hamburg	Dec. 1895	11,700	32.10	34.60	0.94	275.0	43
Hudson	Dec. 1895	535	1.46	0.74	1.98		
Konigsburg	Mar. 1896	1,085	2.97	2.70	1.10	35.0	31
Lawrence	Dec. 1896	1,101	3.02	2.50	1.20	30.0	37
Liverpool—							
Oswestry	Dec 1896	4,460	12.30	4.90	2.52	100.0	45
Rivington	Dec. 1896	4,060	11.10	6.02	1.84	58.0	70
Total	Dec. 1896	8,520	23.40	10.92	2.14	158.0	54
London (rivers only)	Dec. 1896	72,482	198.00	123.75	1.60		
Lubeck	Mar. 1896	1,600	4.38	1.40	3.13	24.4	66
Magdeburg	Mar. 1896	1,950	5.35	3.76	1.42	65.0	30
Mt. Vernon	Dec. 1896	608	1.66	1.10	1.51	9.2	66
Posen	Mar. 1896	346	0.94	0.70	1.35	10.4	33
Poughkeepsie	Dec. 1896	664	1.82	0.68	2.68	9.0	73
Stettin	Mar. 1896	1.030	2.83	2.26	1.25	15.5	66
Stockholm	Dec. 1895	2,375	6 50	2.78	2.33	70.0	34
Stuttgart	Mar. 1896	1,220	3.34	1.66	2.04	17.7	69
Zurich	Dec. 1896	2,360	6.45	1.66	3.88	30 0	79

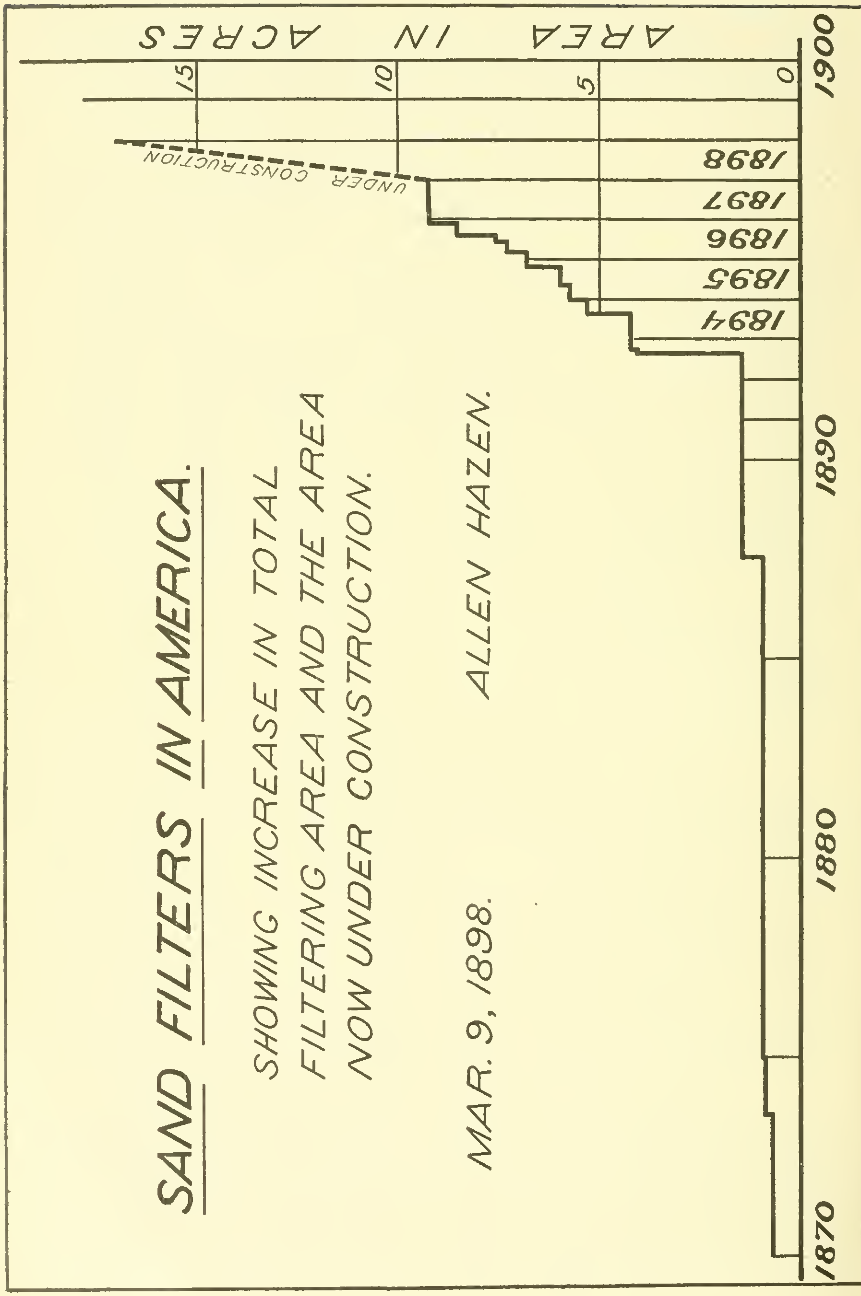
I have also a table of sand filters now in use in the United States and Canada, with their approximate areas, and the dates when they were built, and a list of filters under construction.

SAND FILTERS IN AMERICA.

Place.	Area, Acres.	Built.	In Operation.	Total Area to Date.
Poughkeepsie N.Y., (original)	0.68	1872		0.68
Hudson, N, Y., (original)....	0.21	1874		0.89
St. Johnsbury, Vt...........	0.05	1875(?)		0.94
Hudson, addition...........	0.53	1888		1.47
Nantucket, Mass............	0.11	1892	Aug. 8, 1893	1.58
Lawrence, Mass.............	2.50	1892-3	Sept. 20, 1893	4.08
Ilion, N. Y	0.14	1893	Sept. 30, 1893	4.22
Mt. Vernon, N. Y............	1.10	1894	Aug. 1, 1894	5.32
Grand Forks, N. D	0.42	1894	Jan. 4, 1895	5.74
Milford, Mass...............	0.25		1895	5.99
Victoria. B. C...	0.83		1895	6.82
Ashland, Wis................	0.50	1895	Feb. 5, 1896	7.32
Lambertsville, N. J	0.28		May 4, 1896	7.60
Far Rockaway, N. Y....	0.92	1896	July 1, 1896	8.52
Poughkeepsie, addition.....	0.68	1896	Dec. 17, 1896	9.20
Red Bank, N. J........... .	0.03	1897	June 5, 1897	9.23
Under Construction.				
Somersworth, N. H.....	0.50			
Nyack, N. Y.....	0.39			
Albany, N. Y..	5.70			
Rock Island, Ill............	1.20			

A diagram herewith presented shows the aggregate filter area up to the various dates mentioned, starting with the Poughkeepsie plant back in 1872, followed by the original plant at Hudson, built in 1874, and the little plant at St. Johnsbury, and by the others. The first great increase came with the Lawrence filter and since that time the increase has been rapid. There are something over nine acres of sand filters in use in North America at the present time, and enough more filters are under construction to bring the total area up to something over seventeen acres. The increase has practically all been in the last five years.

I want to ask Mr. Fowler, as to the behavior of the filtered water in his open distributing reservoir. With surface waters open distributing reservoirs are generally considered as good or better than covered reservoirs. With ground water supplies it is considered necessary to exclude the light, to prevent objectionable vegetable


SAND FILTERS IN AMERICA.
SHOWING INCREASE IN TOTAL FILTERING AREA AND THE AREA NOW UNDER CONSTRUCTION.
MAR. 9, 1898.
ALLEN HAZEN.
AREA IN ACRES
0
5
10
15
UNDER CONSTRUCTION
1870
1880
1890
1894
1895
1896
1897
1898
1900

growths. Now filtered river water in its characteristics comes between ground water and surface water, and it has been pretty commonly thought in some places that it was necessary to store filtered water in covered reservoirs. I would like to have Mr. Fowler state, if he will, whether he has observed any objectionable tastes or odors from the growth of organisms in his distributing reservoirs ; and, if there is anyone here from Lawrence, who knows about the Lawrence conditions I wish we could have some information in regard to Lawrence in that connection, and, also, as to whether there is any difference between the new high service reservoir at Lawrence, which is covered, and the old reservoir, which is open?

Mr. Clark. In regard to that matter I will say that at Lawrence they have had in the open reservoir a growth, one or two summers since the filter was put in, of fresh water sponge, which has caused a slight taste and odor in the water, but the sponge grew there before the water was filtered. That is the only thing we have noticed at all. In the stand-pipe the past year there has, of course, been no growth, so far as we could observe, and there was only a very slight growth in the reservoir last summer, nothing that anybody noticed except in a few houses.

There is one thing Mr. Fowler spoke of I should like to mention, and that is the growth of this algæ on the surface of the filter. His filter, I understand, is a continuous filter, and is covered with water except at times of scraping. At the experiment station we have had in operation for some years both continuous and intermittent filters. They were both uncovered until the fall of 1895. During the summer of each year that we operated these filters before covering, there was a growth, generally in September, I think, of this spirogyra, on the surface of the uncovered continuous filter, but it did not grow on the surface of the intermittent filter; neither has it occurred to any extent at the Lawrence city filter. There has been a slight growth in patches here and there from time to time, but nothing that has caused any trouble. Since the fall of 1895 the experimental filters at the station have been covered, that is, we have a board covering over them about three feet above their surface, and there has been no growth of this spirogyra on the filters since that time.

Mr. Fowler also says that the filtration of the river water at Poughkeepsie has not affected the color to any extent. With our

filters at Lawrence we remove about from 30 to 50 per cent of the color at different seasons of the year. In the fall sometimes, when the river water is high and very highly colored with the washings from swamps or woodlands up the river, we do not remove more than 25 to 30 per cent; in other portions of the year we remove 50 per cent. It is different with the Lawrence city filter, of course. As you know, that is built upon a mud bottom, and we have coming into it ground water containing considerable iron, which colors the entire water from the filter to a certain extent. That is to say, the ground water with the iron gets in with the filtered water, and causes an increase of color over what the real filtered water has, but as a general thing, as an average for the year, we have removed 30 per cent of the color from the river water, even after the addition of this iron water.

Now, in regard to the death rate at Lawrence before and since filtration, I presume it is pretty familiar to most of you that for a number of years before we had the filter, typhoid fever was epidemic in Lawrence each year, and we had death rates ranging from 10 to 12 or 13, I believe, per 10,000 inhabitants. The year the filter was built, 1893—it was put in operation the 20th of September—the death rate was a little over 8 per 10,000; in 1894 it was 5 per 10,000; in 1895 it was 3.07 per 10,000; in 1896 1.86 per 10,000; and in 1897 1.62 per 10,000. The death rate from typhoid has certainly gone down. I may say that a little while ago I heard two doctors and one of the undertakers in the city complaining bitterly of dull times in Lawrence. They stated that their occupation was practically gone in the months of the year when they were formerly very busy. [Laughter.] I was talking with a stablekeeper the other day also who has in his stable the wagons and horses of two undertakers, and he said that they had been in about every day for the past two weeks, saying that nobody was dying, and they didn't know whether they should be able to pay their bills; in fact, I think he said they hadn't paid their bills. [Laughter.]

I don't think I have anything further to say in regard to filtered water, except that the death rate and the disease records of the city show that apparently other diseases beside typhoid fever have been lessened. We sometimes have complaints of the appearance of the water and the taste of the water as it is delivered to the consumer. Generally those complaints are from people who live

near the ends of pipes, dead ends, so-called; and there is an accumulation of iron there and stagnant water. But the people who complain the most bitterly, and whose cases we look up by going to their houses to take samples, always say when we get there that the water has no odor that day. [Applause.]

Mr. Fowler. Mr. President, just briefly to answer the questions asked, I will say, first, with reference to odor in our reservoir water, that since I have been in charge there has been no difficulty experienced whatever. I am told that previous to that time there was an occasional odor, that is, this fishy odor which is very common, and it has occurred once or twice since in the dead ends, as was referred to by Mr. Clark; but during my administration no trouble has occurred in the reservoir.

With reference to our filter being continuous, it is continuous in that most of the time the basin is covered, particularly in the winter; but our pumping is not continuous. We pump generally 3½ to 4 days in the week, and the filter works during that time, though we aim to keep the water on the filter. But in the summer time we have sometimes allowed the water to go off the filter and drain dry, hoping that the rays of the sun would kill the alga growth, but it does not do so with us. As soon as we turn the water on it begins to develop again.

With reference to typhoid fever, you notice two instances in my table of very high rates. Now, it is a fact that a number of the cases of typhoid fever in our city originate outside, because we have quite a large number of transient students in our college, and typhoid fever occurs frequently among those, and perhaps the variation in the rate may be due to some such fact as that.

Mr. Clark. There is one thing I should like to add to what I said before, and that is that we still have canal water piped into some of the mills, and a number of the deaths that go to make this record of typhoid fever are of people who have acknowledged drinking the canal water. We have had two deaths from typhoid fever thus far this year, one in January and one in February, and in one case the man acknowledged that he had been in the habit of drinking canal water at the mill.

Mr. Haskell. I would like to ask Mr. Clark if it is not probable that there is less danger from typhoid fever from the use of the filtered water in Lawrence, water taken from the Merrimac and

filtered in their filters, than there would be from an ordinary surface water supply unfiltered?

Mr. Clark. I don't know just what an ordinary surface water supply is. You can have a surface water supply that is perfectly pure, I suppose, from a pond that is not contaminated at all. There are a number of surface supplies in Massachusetts that are contaminated to a certain extent and used without filtration, that is, they are liable to contamination, and I think by using such a water there is more liability of typhoid fever occurring, certainly, than with a filtered water.

Mr. Fowler made some statements in regard to the bacteriological efficiency of the filter. Our filter at Lawrence does better work than his, better bacteriological work. We make analyses of its effluent every day for the largest portion of the year, and I can say that for the past three months, while the average number of bacteria in the river water has been towards 6,000 or 7,000 bacteria per centimetre, I don't think there has been but one or two days when the numbers in the filtered water have averaged over 50, generally down to 25 or 30. We are making a good many additional tests this year. We test the filtered water every day for the presence of coli, the characteristic sewage bacteria; and, while I am not ready to make any statements in regard to those results, I will say that they certainly show an efficiency in that respect that can hardly be shown by percentages. There is a practical elimination of sewage bacteria. And if we do find any, we have generally found a cause for it. There has been something going on in the pumping station, the testing of the pump, and the water allowed to flow back over the floor of the station into the pump well, or something of that sort.

Mr. Haskell. Will Mr. Fowler explain the algæ growth on the bed of this filter?

Mr. Fowler. The algæ growth to which I referred is simply the growth of the plant. It does not affect the water in any way I am aware of, either by odor or taste. It simply grows on the top of the sand and stops filtration, that is the only way it affects us; and the only way we can get rid of it is to stop filtering, drain the bed, and take it off with shovels. It develops on the bed, it is not in the water and taken out on the bed, but it grows on the sand. Perhaps the germs may be in the water, but the algæ, the plant itself, grows on the sand. It will start in a little bit of a speck and grow in a

circle like a dollar until the whole bed is covered as with a blanket.

Mr. Thomas. I would like to inquire of Mr. Fowler if the filtration of the water has increased the hardness to any appreciable extent?

Mr. Fowler. So far as chemical examinations have been made there is no difference, I believe, between the hardness of the unfiltered and the hardness of the filtered water. The total solids are reduced, of course, but I think there is little if any difference in the hardness.

The President. Professor Sedgwick, will you say something on this subject?

Prof. Sedgwick. Mr. President, and gentlemen of the Association, I have suggested to your secretary that this paper is so valuable and so full of material that it ought to be thoroughly discussed by all the members present, who ought to embrace this as a rare opportunity; and that to that end I should be very glad to defer what remarks I was going to make in the form of an informal talk to another occasion. And with that in view, I should like to say one or two things about Mr. Fowler's paper.

This is really a rare occasion. Here is the one man in the United States who has had a long experience with sand filtration of a highly polluted water, in a northern winter, with the ordinary American community to deal with and get his money from—a longer experience, as Mr. Hazen very truly says, than any other man in the United States. He has used a filter built by the eminent Mr. Kirkwood, and one which, so far as I can judge, has on the whole efficiently protected the citizens of Poughkeepsie from typhoid fever.

One or two questions which have been asked suggest the idea that should always be kept in mind, viz:—that typhoid fever does not come entirely from water, so that when the typhoid rate is reduced to a low point, as it has been in Poughkeepsie, and as it has been in Lawrence, we may say that there is no more typhoid fever in a city of that kind with these low figures than there is in many cities having absolutely unobjectionable water supplies, derived from very pure sources. It is necessary to make this statment very squarely and flat-footedly, because one or two engineers in particular have from time to time insisted that as long as there was any typhoid fever in a city, the filter, or water supply, whatever it might be, must be at fault, and that the only remedy is to use distilled water.

Well, that is absolutely false. The right test in these cases is to see whether the amount of typhoid fever remaining after the introduction of the new system, whatever it may be, is any greater than would be found in a similar city supplied with water drawn from perfectly unobjectionable sources.

Now, in the case of the Merrimac river water it is easy to get at that, because there are cities above and below Lawrence that have remarkably good water supplies. They are of the same climatic situation, they have the same late winters and early falls; and they are under the same Divine Providence, which some people still think is responsible for typhoid fever; they are occupied in the same or similar industries, they have just about the same surroundings, the people in the different cities are of similar classes; and with the rate in such cities the rate, for instance in Lawrence, should be compared, and not with the figure zero. There is not a city in the country that hasn't some typhoid fever, and there are many cities in the country that have water supplies which cannot be conceived of as polluted.

It seems to me that the results given here, especially these results in more recent years, when Mr. Fowler has had the advantage of modern sanitary science, are figures which are highly noteworthy; and even the earlier figures, when the filter was run without the modern knowledge of filtration, are also very helpful. The paper is not only full of practical value, but as I look at it has an historic importance; and I for one, sir, am very glad you have consented to read it before this Association, in order that it may go into our JOURNAL and be accessible to all the members of the New England Water Works Association; because we, who are members, believe that this Association does not yield the first place to any such association in the world. We are glad to get papers of this kind, and we appreciate them when we do get them. They are genuine contributions to sanitary science, as well as to the science of water works engineering and management.

I should say that the city of Poughkeepsie had been fortunate in its superintendent. And, while that may seem an empty compliment, let me assure you that it is not so, for there is in all these water supplies the human element. Mr. Fowler discovered it when he found his engineers letting the water run over into the waste-pipe to avoid cleaning the filters. There will always be a human element

in the management of everything. Locomotive engineers will once in a while disregard signals and have collisions, rear-end collisions and the like. Admirals, like the English Admiral on the warship Victoria, will once in a while give directions to turn when there is not room to turn, with the result that they and their ships go to the bottom. There is a human element in all these things, and that water supply is to be esteemed fortunate which has for its administrative officer a man who is persevering, watchful, intelligent and faithful; and such, I believe, most of the water works in New England do have, and all over the country, for that matter. They have to have them, or the people will come to grief.

With regard to the question raised by Mr. Haskell, I had come with considerable talk bottled up on that subject. I am proud that more than a year ago I was able to read a paper before this Association, and that it is printed in our reports, on the Protection of Surface Waters from Pollution. It was the first thing of the kind, so far as I know, that has gone into print, but it is not going to be the last. There have been very serious epidemics in England, particularly within the last six or eight months, three above all others—Maidstone, Lynn, King's Lynn, I believe the full name of it is, and Horsley; where in at least two, and perhaps in all of the cases, a surface water, which had previously been supposed to be pretty pure, that is it was by some, although it had been condemned by others has been the source of very serious damage indeed, and I had come prepared to speak on that subject. But I came with this distinct understanding—it was possible Mr. Fowler might not turn up, and I offered to come only as a stop-gap. I do not propose, therefore, to distract attention, if I could distract it, which I very much doubt, and which I certainly do not want to do, from this very valuable paper. I think an afternoon where we have had reported an experience of seventeen years from a man like Mr. Fowler, on a subject which is certainly the coming subject of water supply all over the world, is an afternoon which has been amply filled, and I do not propose to bring in any other subject at this time.

I do wish to say, however, that Mr. Haskell's question is very well raised. There is no doubt whatever that a surface water which has some little brook sneaking into it, over which privies are hanging, and into which typhoid dejecta are dropping, is a more serious menace to the people using that water than is any

rather badly regulated filter. I would rather take my chances with sewage polluted water filtered intelligently and well, than with a surface water I knew nothing about. And if the time should come when I could give you some extended talk on that subject in amplification of my paper of a year or more ago, I should be very glad to do it, because we are learning every day how serious, as population increases, are the dangers from surface waters not properly watched. It is the watching of the watershed that is our salvation in these cases, and the cleaning of it up. These recent epidemics have set all England in an uproar. I am not exaggerating it one bit. The people are more stirred up in regard to water supply there than they have been for probably twenty-five years.

I happened to be over there this summer, but, unfortunately, the Maidstone epidemic did not occur until just after I reached home. I should have been very glad to have been there and brought you a report of what I could have found on the spot. Since then there have been that great epidemic and two more. It really seems today as though American sanitation in water works affairs was far superior to the English system and practice. The fact is England has been lying on her oars in this matter while America has been forging ahead. And it is a matter of national congratulation, I think, that our water supplies are, as I believe they really are on the whole, our surface water supplies, in better repair and in better condition today, than the average English surface water supplies, for several reasons, which I will not go into now. I wish personally to thank Mr. Fowler for the trouble and time he has taken to prepare and to put this paper on record. It is a matter of congratulation that we have his experiences, and I hope he will come often and give us further chapters from his experience.

Mr. Haskell. There is one other point I wanted to develop to a certain extent in relation to Mr. Fowler's paper, and it is something that ought to seem perfectly surprising, and that is the cost of operating a sand filter. When we think of the vast amount of money individuals are spending in trying to operate some of their filters—I know where they are changing the materials in their filters every three or four weeks, and purchasing quartz in large quantities, —here we find a man who has operated a filter for a long period of years, who has succeeded in getting 97 per cent bacterial efficiency from the use of his filter for a long period, whenever there have

been examinations made, and he has done it all at an expense of less than $3 per million gallons.

Now you all know that the bacteria are the dangerous things in the water. The disagreeable things may not be so fully eliminated, but the dangerous ones have been eliminated by Mr. Fowler to the extent of 97 per cent. And there is hardly any city that could not afford to add $3 a million gallons to the cost of its water, when very likely it costs $85 or $90 a million gallons for maintenance and operation. Calling it $85, it wouldn't add but a small per cent to filter the water. And when we know how easy it is for a camp of gypsies or somebody else to catch around on the edge of a water supply, and stop there, and perhaps send typhoid fever down into the service, or for some of these Italian camps to be located around on a water supply, and that one or two cases of typhoid fever there can produce an epidemic in a city, it does seem as though the attention of everyone ought to be fully brought to the importance of these filters, and also to the cheapness with which they can be supplied and operated.

Prof. Sedgwick. There is one point which Mr. Haskell's remarks remind me of, and which I think ought to be borne in mind when we speak of the efficiency of filtration. We speak, Mr. Fowler has spoken, and Mr. Clark has, and we all do, of the reduction of bacteria as 97, 98 or 99 per cent, and so on. Now what does that mean? It means that there are so many bacteria to a cubic centimetre in the water before filtration, and so many after filtration, and we speak of that as a reduction of so many, or so much per cent. But it ought always to be borne in mind that the real reduction of applied bacteria may be very much greater than that, and for this reason: It often happens that a natural filter is a place where bacteria, fed as they are by a constantly passing stream of water, may somewhat multiply. Those, of course, will only be the harmless water bacteria, at least that is a fair assumption. And I know it has been tried at Lawrence to find a term which should express the thing a little more exactly than to say there was a reduction of 97 or 98 per cent. It is a difficult thing to do, because if you try it, you will find that any expression which really states all the facts is rather long and cumbrous.

There are a great many house filters, for example, which actually give out more bacteria than they take in, but they are perfectly

harmless bacteria, so far as we can judge, from the fact that the people drinking the water seem to be in excellent health and to have no trouble from them at all. But if there are 1 or 2 per cent of bacteria still found in the effluent water, I do not think there is any doubt at all that a certain proportion of those have got to be charged up to the natural development of the bacteria in a filter to which food is coming all the time. It is a place where bacteria reside, and if they reside there they will multiply more or less, so that the real efficiency is higher than the apparent efficiency in all these cases.

And then you will remember that you are dealing with a germ like the typhoid germ, which is all covered over, as it were, with whiskers, it has cilia all over it, and to pass that through sand is very much like trying to pass, for example, a hair brush which has bristles not merely on one side, but all around it. That is a kind of thing that tangles up there far more than the bacteria which are not covered with these lashes, or, as I have roughly called them, whiskers, which cause entanglement. And I haven't the slightest doubt in the world that the real efficiency of these sand filters is far greater than the apparent efficiency. So when it comes up to 99 per cent., for instance, the figure very likely is 100 per cent. of the bacteria actually put on, and especially of bacteria like the typhoid germ. Unfortunately it is not easy to state that.

Everybody assumes that if we put on 100 bacteria, 99 of those bacteria stay there and one of them slips through. Well, sometimes undoubtedly they do slip through, and sometimes undoubtedly they do not slip through, but those which come out below are really those which were raised, perhaps, on the underdrain or in some such place as that. So that the real efficiency of these filters on the whole, in my judgment, is a good deal higher than the apparent efficiency, and for good reasons.

Mr. Haskell. There is one matter, which is very important, connected with the construction of these filters, about which I would like to get some information from Mr. Clark or Prof. Sedgwick. There was a time when we did not consider there could be more than 750,000 gallons of water per acre properly filtered with a good bacterial efficiency. Now, as I read the reports of the State Board of Health, I find that they are increasing in their bacterial efficiency. I really think they have got nearly to ten million gallons per acre

per 24 hours, and I think they have maintained for the year continuous work as good as 99.70 to 99.73 per cent. Now that means a good deal in the construction of a filter, and if we can get that fine work through a continuous filter, I should like to know it, and I didn't know but Mr. Clark or Prof. Sedgwick could tell us.

Mr. Clark. We have never operated any filters at so high a rate as 10,000,000 gallons except for a few weeks at a time, and then we have got apparently very good results. But, taking the filters which we have been operating for a number of years at the experiment station, the average rate of filtration has been rather less than 4,000,000, three million six or seven hundred thousand, with our largest and best sand filters. I myself believe that with careful handling of a small plant, with intelligent direction, you can perhaps filter a water, something nearly as badly polluted as the Merrimac river water, at a rate approximating 4,000,000 gallons per acre daily, but I think that a safe rate is 3,000,000 gallons, with the care which the filters on a large scale would generally receive. I, certainly, if I was building filters, or recommending filters for any municipality, should not advise that the rate be over 3,000,000 gallons per acre daily. I think that the economy in running a filter at the rate of 3,000,000 gallons is greater than at the rate of 5,000,000; that is, I think there will be more scraping, more washing of sand and changing of sand at the rate of 5,000,000 than at the rate of 3,000,000, that is, a greater cost per million gallons of water filtered. This whole question depends, however, upon the character of the water to be filtered.

Mr. Fowler. Mr. President, may I be allowed one word with reference to that point. I think that in examining the paper, which the gentlemen have been so kind as to speak so favorably of here, one thing will be prominent, and that is that a larger area is necessary in constructing filters than just the area sufficient to do good work when everything is in perfect order. Therefore, if 3,000,000 gallons, which I fully agree with Mr. Clark ought not to be exceeded, is the quantity wanted per day, we should have a certain amount in excess, in order that we may always have our area for 3,000,000 gallons per day in perfect order. I find that the great trouble with my work. I worked for 16 years with one filter

of the size I gave you, two-thirds of an acre in extent. Now we have just built a new filter equal in area to that, giving us one and one-third acres. If we were to operate an uncovered filter, I should not consider the plant perfect for use until we had one more filter of one-third of an acre in area, that is in order that it might be in perfect order at all times. Of course that is something I don't expect to get, probably, during my administration; but I shall not say that our plant is perfect for our city until we have a little more surface, so I may always have the two I now have in perfect order.

Mr. Haskell. It seems to me that perhaps Mr. Clark is a little too modest about telling us of the final results they have secured up there in Lawrence in some of their experiments. My memory is not as good as it was once, but I have read the reports each year, and if I remember correctly, filter A, I forget the number now, it may be 58, has been operated for 11 years. They operated it in different ways and they did very good work with it, and they finally thought they would construct a filter as near as they could under the conditions which would apply to an ordinary water supply, and they have operated that now, I should think, about six years. It was run at the rate of over 4,000,000 per day of 24 hours, and practically run continuously for the term of four years. And I think by the report for 1896, it appears that for the three years run at that rapid rate continuously the percentages were 99.70, 99.73 and 99.50. Now it did do nearly as good work as that, didn't it, Mr. Clark, although you wouldn't fully recommend it, and it did it under conditions copying as near as possible a practical filter!

Mr. Clark. I said, Mr. President, that I thought small filters, with careful watching hour by hour, with intelligent management, could be operated at these high rates. When I said "small filters," I meant filters such as we are running at the Lawrence experiment station. I have no doubt however that a filter with a surface area of an acre or half an acre, receiving water like the Merrimac river water, can be operated, if extreme care is given to it, at a rate approximating 4,000,000 gallons per acre daily; but I believe a safer rate is a little lower than that, and I do not think, with my

present knowledge of the subject and my present experience in operating filters, I should ever advise a rate as high as 4,000,000 gallons, with such water as the Merrimac river water. Still we have got for the past four years extremely good results with an experimental filter, 17 feet in diameter, running at a rate approximating four millions; I don't think the average has been four millions. I think it has been about 3,600,000 for the four years.

MR. HAZEN. I have come to the conclusion that different waters can be filtered at different rates, and that it is perfectly possible to filter some waters with high bacterial efficiency, at rates at least twice as high as can be successfully used with other waters. I am not going to tell you all the conditions which influence or control the possible rate of filtration, principally because I do not fully understand them myself, although we are learning something about them. In regard to the efficiency that is secured by the operation of filters, there is the efficiency which is gotten when the filter is in perfect condition, and there is the efficiency which is gotten when the filter is in a defective condition. And I think that the lower bacterial efficiencies resulting from defective conditions have been a good deal more common than has been generally supposed.

One of the commonest defects of a filter plant is for the unfiltered water in some way or other to get around the sand into the under drains. Mr. Fowler told you how it went through his ventilator pipes. Filters have been built without any ventilator pipes, and they work just as well without them, and this danger is avoided. Sometimes the sand will cake a little, and it will draw away from the wall, and the unfiltered water will run down the wall. We have corrected that by putting some little ledges or jogs in the wall, and the sand makes a better joint on a horizontal surface than on a vertical surface. That was a good idea as far as it went, but even with those jogs the masonry may sometimes crack, and the water leak into a crack above the sand line and come out of a crack below the sand line. Now we are building filters keeping the gravel back from the outside walls all the way around. It perhaps reduces the area of the filter a little theoretically, but if the water comes down the wall in some way, it has to pass along the bottom through the sand before it gets into the underdrains. We

keep finding out such things as that. Mr. Haskell asked me today if we were ready to build a perfect filter. I told him no, we didn't expect to build a perfect filter for a long time yet, but we are building as good filters as we can, and are learning more about how to do it all the time, and are building filters which will do very good work, even if they are not perfect.

LOSS OF WATER FROM PIPES.

BY F. H. CRANDALL, SUPT., BURLINGTON, VT.

[*Read February 9, 1898.*]

The determination of the loss of water from any considerable system of underground piping is at best problematical and does not admit of definite unquestionable solution, but in the case which I will endeavor to present for your consideration, some of the difficulties ordinarily encountered have been eliminated.

Systems, even of such small extent as that to which your attention is invited, on which for months at a time there is no occasion to open public fire hydrants, on which there are no large manufacturing concerns using water for fire purposes and on which all ordinary legitimate use is metered, are not numerous. On the Burlington High Service, however, it has recently come about that these conditions obtain.

By far the larger portion of the pumpage on this service is accomplished by a motor, an auxiliary steam plant being used only when for one reason or another it becomes necessary. The works were built in 1880 and 1881 and now supply the University buildings, the State Agricultural Experiment Station and farm buildings, two Roman Catholic schools, one hospital and five summer residences with innumerable fixtures, beside 45 dwellings, nearly all of which are supplied with modern conveniences in plumbing. Some of the mains were laid in rock cut and some are for the greater portion of the year, below the ground water level. No more than usual care was taken in the laying, and no more than the usual amount of trouble has been experienced from them since. The work was not contracted.

The average pressure on fixtures is about 35 pounds, and on the majority of the services (on those of all the larger consumers), a main tank with supply controlled by a ball-cock covers nearly all the fixtures.

The service comprises an iron tank of 2,260 cubic feet capacity, 9,671 feet of cast iron mains from 4 to 8 inches in diameter, and about 1,560 feet of 4-inch cement mains, with six public fire hydrants, one 4-inch and two 2-inch services supposed to be used for fire purposes only, 62 metered taps through which water is used for domestic purposes, one 3-inch metered elevator service, one 2-inch overflow, metered, and one 1¼-inch metered service used to supply power for operating valves of the motor.

The meters in use on the service are of the Crown, Nash, Empire, Bee, Lambert, Union Rotary, Union Piston, Disc and Trident make. Each of the meters used on the service at the time of setting, registered on full size ⅛-inch and 1-16-inch streams not more than two per cent fast nor more than 3 per cent slow. By sizes, the meters in use are one 3-inch, two 2-inch, two 1½-inch, seven 1-inch, seven ¾-inch, forty-one ½-inch, and five ⅝-inch.

As the discharge of the motor is conveyed to the tank by way of the distribution system, and thus far conditions have not been favorable for accurate measurement, the losses in the pump can be got at only by estimation.

The plunger in the pump end of the motor, which works against about 41 pounds static, 43 dynamic head, is 4 and 7-16-inches in diameter, and is provided with a double cup leather packing, which has frequently been found, when the plunger is not in motion, to be absolutely tight at different points of the stroke. In motion a small leakage is developed. There is also leakage of the ports, and though at different times when the motor has been opened for repairs, the high service pressure being applied on the pump side, there has been no leakage noted through the leather packed stuffing-box between pump and motor, in practice there must be some leakage at this point.

The motor and pump are set up tandem, and at the other end of the rod, to which is attached the pump plunger, another and a larger plunger in the motor barrel is attached. These plungers and their rod passing through the aforementioned stuffing-box in the head common to both motor and pump have, when at work, more or less rotative motion.

The leakage through this stuffing-box, between the pump and motor, cannot conveniently be separated from that through two 10-inch gates under the low service pressure (about five pounds). All

three together have frequently been found to amount to less than one per cent, and in the different tests made it has developed that reliable information is not to be obtained from the measurement alternately for equal intervals of the total leakage and that from the gates alone, as the leakage of the two gates alone was often in excess of that of gates and stuffing-box taken together.

The suction and discharge ports of the motor pump are each 12 in number, about three inches in diameter and capable of one-half inch lift. The motor runs at from 4 to 32 strokes per minute and will not run many minutes at the maximum speed. The average is about sixteen strokes per minute.

Beside the losses common to all pumps a further source of error in the counter measurement in this case is the shortening of the stroke on small streams such as obtains in some meters, and which in this case at times reaches three per cent of the stroke. It is not, however, expected that in practice the motor will be required to run for any considerable length of time on a very small flow.

In the endeavor to obtain some idea of the tightness of the pump plunger when in motion, motion was imparted to it when under pressure by means of a rod threaded for the full length of the stroke and operated through a threaded hole in a bar bolted across the opening made by the removal of the cylinder head.

The motor is supplied with a regular pump counter and the record of its strokes is probably as accurate as is generally obtained. The pumpage of the steam plant was, perhaps, not as accurately determined. It was taken to be the increase in depth of water in the tank during the time of its operation, which usually took place at times when there was little or no consumption.

The records for the two periods into which the total period may be divided, during one of which the steam pump was used and the average daily consumption was about 4,770 cubic feet and during the other of which the steam pump was not used and the average daily consumption was about 3,552 cubic feet, do not differ materially in the percentages not measured.

In taking statements of the meters recording the consumption, about two hours are consumed, and the counter of the motor is read during that time. For very short periods the pumpage during the time of taking statements and a slight variation of depth in the tank tending in the same direction would have a noticeable effect,

but for long periods any error which could arise from these causes is so slight as to be neglectable.

In determining the correction to be applied to the counter record for losses on the pump, taking the leakage of the ports at the mean noted during several tests, made under static pressure, that of the plunger at the mean noted while moving with considerable less than its usual velocity against the static pressure and that of the stuffing-box at an arbitrarily chosen amount equal to one-half that of the plunger, we have an aggregate loss, under the conditions noted of about one per cent, and for purposes of estimation we will assume the losses under working conditions at five per cent.

Records are at present obtainable of the pumpage and consumption on this service for a period of eleven months, during which every legitimate use of water, except such as made by the water department, was supplied through meters. During the period under consideration there was no occasion for the use of water for fire purposes on the high service.

During the first eight months for which records are kept, the steam plant was called upon but five times. The total amount of water handled was 1,144,907 cubic feet. 1,088,563 cubic feet, or about 95 per cent by the motor, (as per indicator), and 56,344 cubic feet, about 5 per cent by the steam plant. (Determined as before stated). Of this indicated pumpage,

729,282	cubic feet,	about	64	per cent,	was metered to consumers.
193,285	"	"	17	"	" " " motor.
39,040	"	"	3	"	" " " overflow.
27,630	"	"	2	"	" estimated to consumers.
57,245	"	"	5	"	" the estimated loss in pump.
98,425	"	"	9	"	not accounted for.

During the last three months for which records are obtainable, the steam plant was not called upon at all. The total amount of water handled was (as per indicator) 319,734 cubic feet. Of this indicated pumpage,

230,375	cubic feet,	about	72	per cent,	was metered to consumers.
40,360	"	"	13	"	" " " motor.
1,680	"	"	5	"	" " " overflow.
2,024	"	"	5	"	" estimated to consumers.
15,986	"	"	5	"	" " loss in pump.
29,309	"	"	9	"	not accounted for.

During the entire period for which records are available, eleven months ending February 1st, 1898, the total amount of water handled was 1,464,641 cubic feet—1,408,297 cubic feet, or about 96 per cent by the motor (as per indicator) and 56,344 cubic feet, about 4 per cent by the steam plant. (Determined as before stated). Of this indicated pumpage,

959,657	cubic feet,	about	65	per cent	was metered to consumers.
233,645	"	"	16	"	" " " motor.
40,720	"	"	3	"	" " " overflow.
29,654	"	"	2	"	" estimated to consumers.
73,232	"	"	5	"	" the estimated loss in pump.
127,733	"	"	9	"	not accounted for.

DISCUSSION.

THE PRESIDENT. Mr. Brackett, I think you have had something to say heretofore on loss of water from leakage and other causes.

MR. BRACKETT. I think that might perhaps be a good reason why I should not have anything to say now, and I do not know that I have anything new to say on this subject. It has been one to which I have given considerable attention, but not for some two or three years. I should think that a loss of nine per cent, which Mr. Crandall reports, was somewhat less than has been observed in other cases. Of course in his case he had a comparatively short pipe system, and with a larger and possibly older system, I think the loss would be greater. In some cases I have known of, where almost all the water that was pumped was metered, the loss has been as high as thirty per cent. The difference is supposed to be due to leaky mains. Perhaps that statement had better be qualified by saying leakage from mains and loss from the meters. Of course we all know that meters that have been in service long enough will have a certain loss, so a portion of that thirty per cent should be charged to the loss through the meters.

MR. WHITNEY. I should like to ask Mr. Crandall how long those meters had been in use at the time he made the experiments?

MR. CRANDALL. Some of the meters had been in use ten or twelve years, but just prior to the commencement of the test every meter was overhauled and tested, and when the test began, they had within a month of that time, been found to register within the per cent named.

MR. RICHARDS. I would like to ask Mr. Crandall if the pump plunger always completed its stroke, if it made the entire stroke every time?

MR. CRANDALL. I called attention to the fact that in the motor, as in some makes of meters, on small streams or slow velocities, there is a shortage in the stroke, which, in this case, I thought amounted to fully three per cent of the stroke, but that in practice we do not expect our motor runs much of the time with so short a stroke as that. I allowed three per cent as the loss on that one account, and the other two per cent was for ordinary losses through valves and leakage past the plunger.

MR. RICHARDS. I think there is no doubt but that there is a very considerable leakage in mains very often, not large in any one place, but very small in a great many places, and that the sum total amounts to a big figure. It often happens, as we all know, that there may be a big leakage in one place which we do not discover, yet I think the leakage comes mainly from very small joint leaks in a great many places.

THE PRESIDENT. Mr. Kieran, can you give us some information in regard to loss of water in Fall River?

MR. KIERAN. Mr. President and gentlemen: I am sorry to say that our loss is much greater than Mr. Crandall's as far as we can get at it. During the past year we have been making some investigations, and we found that the loss was 40 per cent, that is taking the whole pumpage, and taking the whole supply for the town. We have one and not two systems (as I understand Mr. Crandall his experiment has been made on the high service) and it is most all metered. The greater part of our consumers are metered, and over 90 per cent of our revenue comes from the metered service. But our city is supplied for all public institutions and places free, and they use the water pretty freely too. This year I hope we shall be able to stop a great deal of it, for the reason that we have been metering the public places, schools and stables and the City Hall, watering troughs, parks, etc. Up to the first of the year we lost 41 per cent which we cannot account for. We made an estimate for the city stable based on what we have been receiving from a private stable, or a boarding stable, where we have had a meter set. We allowed the same amount, but on placing a meter there we found they were using over three times that amount, where there were no

carriages to wash, simply horses to water. We supposed that washing carriages would offset quite a waste, but we found it did not. The city stable with fifty-six horses has used over three times as much as was used in the boarding stable with seventy-five horses. I hope this season we shall be able to get at some of that waste, and possibly we can. We have taken our full rate consumers and have placed them on the same ratio with the metered takers; and for all stopped meters we find during the quarter, we make an estimate on the basis of the same quarter of the previous year, and call it the same number of feet.

Mr. Brackett. I would like to ask Mr. Kieran if the 40 per cent includes the whole use by the city? That is, whether the 60 per cent which you have measured or can account for is simply what is metered, and the 40 per cent includes all other uses?

Mr. Kieran. The 40 per cent is the actual loss, what we can not account for after estimating for public purposes. That is the actual loss.

Mr. Stacey. Perhaps some of that can be accounted for in the way we are trying to account for some of our water. For all our school buildings we get $6 a year. We came to the conclusion we would put on a meter at one of the schools, and the first three months it ran 21,000 cubic feet. We thought that was accounting for some of the water we could not account for otherwise.

Mr. Crandall. Speaking about accounting for water used for public purposes, I think I can add a pretty good story which is true. Our public buildings and parks committee decided on the 31st of July last that they were being overcharged at the schedule rates, and that they would in the future pay the meter rate. We had for the previous year, and for the previous months of last year, had meters on the park services for our own information, although they had paid the schedule rate during that time. On footing up at the close of the season, I found that for the months since the 31st of July when they were paying at meter rates, they had used about one-fourth as much water as they did during the preceding months of the same year; I mean, the rate per day was about one-fourth the rate during the preceding months, and the preceding months were the wet months of the season. They had used during the period for which they were paying meter rates about one-fifth what they used the preceding season; I am speaking of the rate

per day each time. We find it is very difficult to make the individual consumer understand why he should practice economy, when he sees water being wasted in public places at the rate I have just spoken of.

Mr. Holden. I would like to inquire of Mr. Crandall what the cost of this motor was, and how much the expense of keeping it in repair was.

Mr. Crandall. Our motor is a small one ; it is for a 10-inch main. It was put in before I had anything to do with the water works, but if I remember rightly, it cost about $2,000. The cost for maintenance, that is the care of the machine, for no automatic machine will run without care, and the cost of repairs, charging it whatever gas is burned, and anything that is used at that place, has amounted to less than $400 per annum since I have been on the works. Mr. Richards has a much larger motor, and he probably remembers just what that cost.

Mr. Richards. Our motor is larger, and pumps more water. My recollection is that the motor cost about $5,000, and the cost of maintenance is about $300 a year.

Mr. Crandall. In my cost for maintenance I am including the proportionate part of the fuel that is used for pumping water at the low service. The motor runs in either direction. We can make it run by pumping water into the reservoir, or it will run when the pumps stop ; without any action on our part, it will automatically reverse itself. Mr. Richards' motor only runs one way, there is no occasion for running it the other way. In our case, when the motor is run by the pump, there is five pounds additional pressure, and a certain per cent of fuel used at the low station is properly chargeable to the high station, but in the figures is included the per cent of fuel which would be used did the motor run all the time, which it does not.

Mr. Fuller. In Wellesley we meter all the water that is consumed, or attempt to, and I think during the month of December—if I had known this matter was coming up I would have looked it up a little more carefully—I think we accounted for 67 per cent of the water we supposed we had pumped. We do not meter the water as we pump it, as it goes into the mains, but I think in the spring we shall attempt to do that. This comparison is based on allowing, I think it is, 3 per cent slip on the pump, and using about

the full length of the stroke of the pump. I know we lose something by small leaks through the meters that is not recorded, but we have tested our pipe system and are sure that there are no large leaks there, probably there are some small leaks, and it seems to be quite a problem to account for this apparent discrepancy in the amount of water pumped and what is recorded.

MR. WHITNEY. Isn't it probable, Mr. Crandall, that your low pressure on this section accounts for the very large percentage which you can seem to find of the water pumped? What I mean is, is it not probable that on a regular water system with heavy pressure, dribbling ball cocks, the water for which is not registered by the meters, oftentimes accounts for a very large percentage of this water which is lost?

MR. CRANDALL. There is no doubt in my mind that an increase of the pressure would increase the amount unaccounted for.

LAYING A 24-INCH MAIN UNDER THE NASHUA RIVER.

BY HORACE G. HOLDEN, SUPT., NASHUA, N. H.

[*Read February 9, 1898.*]

The city of Nashua is located on both sides of the Nashua river near its junction with the Merrimack. It is fourteen miles above Lowell, and seventeen miles below Manchester. The entire water supply for domestic use, steam boilers and fire protection is furnished by the Pennichuck Water Works.

The water is taken from a system of ponds and reservoirs fed by springs and the Pennichuck brook about two miles north of the city, being pumped through two lines of cast iron pipe, 24-inch and 16-inch. These two lines unite near the center of the city into one 24-inch line, the whole length of the 24-inch pipe being about three miles.

In crossing the Nashua river the pipes are suspended under a "lattice bridge." Although the bridge has held the water pipes safely for forty-four years, an accident might at any time occur to the bridge; by which a large portion of the city would be left with a very limited supply of water. For this reason it was deemed advisable to lay a separate 24-inch pipe under the river and connect it with the main 24-inch near each end of the bridge, forming a loop, so that in case of any accident to the bridge the water supply could pass under the river, which at this point is about 250 feet wide, with an average depth of 18 feet.

Owing to difficulties about obtaining a right of way to the river, the crossing had to be made about 150 feet above the bridge, the submerged part requiring twenty-two lengths or 264 feet of pipe having the "Ward joint."

[A model of a "Ward joint" was here exhibited.]

You will notice by the model that the bell is larger and deeper than in the common joint, and that the inside of the bell is turned similiar to a hollow sphere, while the spigot has two ribs running

around the pipe. These ribs are seven-eighths of an inch less in diameter than the inside of the bell, so that after the lead is poured there will be seven-sixteenths of an inch of lead in the thinnest part of the joint, while the ribs serve to hold the lead in place and prevent the joint from pulling out.

The south bank of the river at this place had for many years been used as a dumping ground for the refuse from the neighboring factories. This necessitated the grading of the bank, starting about fifty feet from the edge of the river and sloping into the river for several feet, in order to prevent too great a bend in any one joint. The pipes were put together on the slope, being laid on rolls resting on plank. The first pipe used had an ordinary bell end, which was plugged tight. The other end of the pipe had a "Ward joint bell," and into this the spigot end of the next pipe was firmly leaded, about one hundred and fifty pounds of lead being required for each joint. As fast as the pipes were put together they were secured from pulling apart by a heavy cable lashed twice around each pipe, and six to eight empty oil barrels secured to these lashings to keep the pipe from sinking. Then with a windlass on the opposite bank the line of pipe was gradually drawn across, the rear of the line being held by snub lines which prevented the pipe from going to the river any faster than the joints were completed.

After the submerged part was finished and the pipe line stretched from shore to shore, being held up by 175 empty barrels, the pipe was then filled with water from a neighboring hydrant. This caused it to gradually settle, and upon cutting the lashings to the barrels in various places along the line, the pipe slowly sunk to the bottom of the river, and then the line was extended from both banks to the pipes on the main street near each end of the bridge.

The unusual spectacle of a 24-inch pipe line being lowered to the bottom of the Nashua river drew a large gathering of spectators, and the Nashua bridge was crowded with people watching the operation, among whom was the ever present newspaper correspondent, and the next day the Boston *Post's* "Observant Citizen," who evidently was not up to date on submerged pipe laying, broke loose as follows: "I was in Nashua yesterday and was much amused, while waiting for a train, by watching the rather primitive methods of a crew of workmen engaged in placing a water main across the bed of the Nashua river. Wishing to suspend the pipe

until the divers could arrange the supports under them, they employed empty barrels to float the pipes. Unfortunately the casks had been used for oil, and as soon as the weight of the pipe was applied, the ropes would slip from the barrels, sending them bobbing around in all directions. The current did not particularly facilitate the efforts of the disgusted workmen in reassembling them.''

The facts of the case were that the barrels were lashed to the pipes to lift them. When "Observant Citizen'' saw the barrels, the diver was on the river bottom cutting the lashings and allowing them to escape. This was for the purpose of lowering the pipe to its place on the bed of the river. The work may have been primitive, but it accomplished the purpose for which it was intended, and the only workmen were the diver and his two assistants.

After setting 24-inch water gates at each end of the submerged line the street pressure, which at this place is about seventy pounds, was let on, and in order to test the line for any leaks two $\frac{5}{8}$-inch corporation cocks were tapped into one of the pipes on the south bank of the river. A test gauge was placed on one of these cocks, and from the other a line of 1-inch pipe was laid and connected with a service pipe from a neighboring building. On this line was placed a $\frac{5}{8}$-inch meter which had been carefully tested, also a force pump capable of raising the pressure to 100 pounds to the square inch. The first test showed a leakage of about two gallons per minute and on examination of the pipe line by a diver small leaks were found in several of the joints. These were then carefully caulked, and at the present time the leakage is greatly reduced— the last test showing about thirty gallons per hour. It is my intention next season to have the whole line perfectly tight.

The pipe for this job was furnished by the Warren Foundry & Machine Co. The work on the submerged portion was done by the well-known diver and contractor George W. Townsend of Boston.

DISCUSSION.

Mr. Crandall. I would like to ask Mr. Holden if there was any preparation of the bottom made for this pipe line, before it was lowered into position?

Mr. Holden. The bottom of the river was very smooth; there

were no stones of any amount, and there was a hard gravel bottom on the south shore. On the north shore was a little mud, so the pipe settled down. We didn't have to make any preparation whatever, and as the pipe lies, I had it examined by one of my own men with a diving suit; he found every pipe was well bedded on the bottom of the river.

THE PRESIDENT. Mr. Brackett, I think you have recently had some experience in laying pipe across or under rivers?

MR. BRACKETT. I think some of the other members, who have done the work, can perhaps, tell better about this work, than I. I think Mr. Gowing can tell you about one section which has been laid.

THE PRESIDENT. We would be very glad to hear from Mr. Gowing. Perhaps Mr. Brackett could tell us how it was proposed to do it and Mr. Gowing could tell us how it was done.

MR. GOWING. We laid a pipe across the Malden river, but the pipe laying part of it was not difficult at all, because we put in a coffer-dam and pumped it out dry, and then we laid the pipe just as if it were on dry land. Where that can be done, of course, it is very much better than any Ward joint, or anything of the sort, I think. It is a good deal more expensive, it would have been more expensive to have laid the pipe across the Nashua river in the way we laid it across the Malden river, than to lay it as it was laid. But I think the Metropolitan Water Board has one satisfaction for the money they spent, and that is they have got a tight line. I wasn't there when it was tested, but they told me that the meter refused to work, and I don't believe they will ever have any trouble and if they get 10, 20 or 30 per cent loss, it won't be on our line.

MR. BRACKETT. We have laid three large lines of pipe across rivers, but I do not think at the present time I can give you full details of the work. If it would be of interest, I might tell you in a general way how the work has been done.

In crossing the Malden river, of which Mr. Gowing speaks, we considered that it was better to lay the pipe by means of a coffer-dam than it was to use flexible joints and lower the pipe into a dredged trench. It may be, perhaps, that there were peculiar circumstances in this case.

We had two crossings of the Charles river and one of the Mystic river. One of those on the Charles was about 600 feet in length, the other about 400 feet, and the one on the Mystic was 1,200 feet.

They are all in connection with 48-inch pipe lines, and we have used a double 36-inch pipe line at each river crossing, to prevent the entire loss of the main in case of any leak on one of the lines crossing the river, and also for convenience in doing the work. The pipes which have been used, the pipe being laid in salt water, have been made very heavy; the 36-inch pipe is 1.65 inches in thickness, and weigh 677 pounds per foot, which is very much heavier than is used even for 48-inch pipe.

There were three types of joint used on the lines. One is the ordinary joint, with the exception that in place of one lead score there were three, for more firmly holding the lead.

The second type had a turned spigot end, with a very slight taper, about a sixteenth of an inch in five inches. And in the socket or bell of the connecting pipe the lead was cast, and then the spigot end was withdrawn and jointed under water afterward.

The third type was a ball and socket joint similar to the Ward joint, the difference being that the lead is cast into the bell rather than being cast on to the spigot, so that when the joint turns the lead is not drawn out of the bell. Flexible joints were only used at changes in the vertical line of the pipe.

The pipes were made up on the shore in sections, generally of six lengths of pipe, and at one end of each section was a turned tapered spigot, the bell at the other end having the lead cast in to receive the spigot end of a section which had already been laid. The whole section was suspended on a truss hung from derricks on a scow, and then lowered into position, in a dredged trench in the river. The diver entered the spigot end of the tapered pipe into the bell, or into a guide which was bolted to the bell end of the pipe which was being lowered, and then by hydraulic power, applied through a cylinder and piston attached to the truss, the pipes were drawn together, and they were afterwards caulked by a diver. That is in general the method in which the work has been done.

At the crossing of the Mystic river, the entire length of 1,200 feet of pipes were laid on a pile foundation, consisting of a 10x10 cap placed crosswise of the line of pipe back of the bell of each length, and supported by two spruce piles. On the other lines the pipes rest in the earth for the greater part of the distance, but are on piles near the shore where there was a soft bottom.

Mr. Winslow. Weren't those bottoms prepared for the pipes

independently of the piling, so as to carry them below the bottom of the river, so they were covered with earth?

MR. BRACKETT. The pipes were all laid in dredged channels, and were afterwards covered, so that they are below the bed of the river and not liable to be damaged by any vessels even grounding on them.

MR. HOLDEN. What amount of leakage do you get on your submerged pipe in the Charles river?

MR. BRACKETT. I stated I could not give you all the details. I know there has been some leakage, but I haven't the figures. However, they are reasonably tight.

MR. HOLDEN. In making out the contract for laying the pipe, of which I have spoken, I used the same specifications that Mr. Brackett used on the Charles river pipe—that is, that the leakage should not be over a tenth of a gallon per running foot per hour, which in our case would be 26.4 gallons per hour. At present the leakage does not amount to any more than that; it is just about that now.

MR. GILBERT. I might relate a little experience I had with laying a 12-inch pipe in the water some ten years ago. I wanted to lay it about 100 feet into a pond, so as to get the end of the pipe out into deep water. I made arrangements for putting it together on shore, and then shoving it out. I made preparations by getting oil barrels, making a number of rafts, etc., and got everything in readiness. We got the pipe started out into the water, and attached the oil barrels, and as we put in a piece of pipe we would shove it out. It worked nicely, and I was very much pleased with our success, as I had anticipated a great deal of trouble in keeping the pipe on top of the water. We had the end of the pipe plugged up tight, and after getting it out about 100 feet, we got on to the rafts and cut loose our oil barrels. After we cut the oil barrels all away, and got the rafts out, our pipe still laid on the top of the water, and we couldn't sink it, it wouldn't go down anyway. Finally we knocked the plug out of the end, and the pipe slowly sank to the bottom.

THE PRESIDENT. I am told that Mr. Crandall has had considerable experience in laying pipe under water.

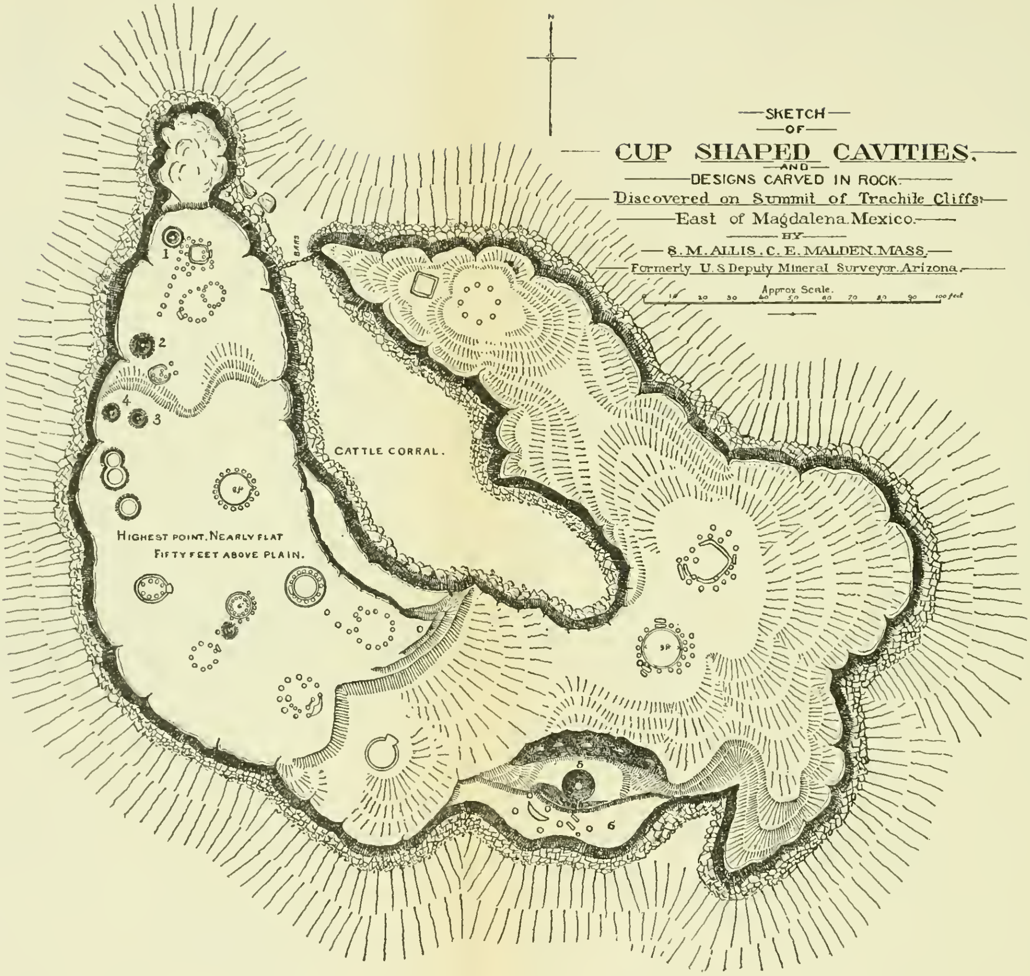
MR. CRANDALL. We laid about three miles of 24-inch on the bottom of Lake Champlain, in 1894. Mr. Falcon of Evanston, Illinois, had the contract, being the lowest bidder, and we used one

of his patent joints on every six lengths. I think he could have laid 600 feet a day if he had wished to ; but he did not want our citizens to know he had such a snap, I think, so he did not work quite as fast as that. The bottom of the lake is sand for the entire distance, overlaid with a more or less thin layer of mud, and experiments indicated that the pipe would settle through the mud on to the sand ; and in lowering the pipe it was found that it did immediately reach a bed. And at the time of laying the last lengths, which was several months after the laying of the first, the first lengths had not settled any from their first position.

There were two summits in the three miles, and openings were left at those summits, by tapping a brass tube into the top of the 24-inch pipe at as near the summit as we could get it, and tapping small holes through the brass tube. If I remember rightly, there are four one-eighth inch holes through the brass tube at each of the summits. The conduit when completed was tested by filling with water under 20 pounds pressure. I do not remember just what we specified for leakage, but the contractor was inside the limit. Since then tests have been made which showed that the leakage was diminishing. It was tested in 1895 and in 1896, and in 1895 the result was better than in 1894, and in 1896 it was better than in 1895. And when I say "better" I simply mean better ; I do not mean to say very much better, but it was not worse.

Mr. Whitney. I would like to ask Mr. Crandall how the joint he used, the flexible joint, differs from this Ward joint which has been shown here today?

Mr. Crandall. The Falcon joint on the spigot end is spherical, and the bell end has a flanged cup into which this sphere projects, and there is a ring which it is necessary to slip on over the back side of the spigot. It will not pull over the turned sphere of the spigot even with no lead in. After slipping it over the spigot from the back side it is leaded. Then the flange on the ring is bolted to the flange of the bell, which is leaded to the other length to which it is to be joined under water. The joint made under water is a flange joint. In our case, which was a 24-inch pipe, if I remember rightly, there were twenty-six bolts, and, I think Mr. Falcon did the tightening up of the twenty-six bolts in a little less than twenty-six minutes. I went down afterwards to see if he had done it, on a bet, and I was unable to make it any tighter on any one of the bolts.


N
SKETCH
OF
CUP SHAPED CAVITIES,
AND
DESIGNS CARVED IN ROCK.
Discovered on Summit of Trachile Cliffs:
East of Magdalena. Mexico.
BY
S. M. ALLIS. C. E. MALDEN. MASS.
Formerly U. S Deputy Mineral Surveyor. Arizona.
Approx Scale.
0 10 20 30 40 50 60 70 80 90 100 feet
BARS
1
2
3
4
5
6
CATTLE CORRAL.
HIGHEST POINT. NEARLY FLAT
FIFTY FEET ABOVE PLAIN.

EXPERIENCES IN THE "ARID SOUTHWEST."

BY SOLON M. ALLIS, C. E., MALDEN, MASS., FORMERLY U. S. DEPUTY MINERAL SURVEYOR, TUCSON, ARIZONA.

[*Read February 9, 1898.*]

Having spent some years mining and surveying in the extreme southwest of Uncle Sam's territories, and in Northern Sonora, Mexico, I was much impressed by the difficulties experienced in getting water for irrigation, and in many places for camp use. This difficulty is mainly caused by the physical features of the country which I will briefly notice.

Although Arizona has in its northern area an extreme elevation of 6,000 feet above the sea and mountain ranges that originate never failing streams of good size, such as the Gila and Salt rivers, yet we find a very large area in the southwest where the low lying plains rise from 12 feet above the sea at Yuma, to 2,500 feet at Tucson, distant 220 miles south of east. These low lying plains are diversified by small detached mountain peaks and ranges of no great altitude, but of forbidding aspect, as bare and rocky they glisten in the terrific heat of the summer months.

These give rise to different drainage areas, and the dry "arroyos," devoid of water during a large portion of the year, become in the wet season full of water, which sometimes comes from cloud bursts, resulting in raging torrents, generally, however, of very short duration.

On the eastern portion of this large area, and where the elevation becomes 10,000 feet and upwards, some of the streams have water the year round, as, for instance, the San Pedro which flows northerly into the Gila, its valley being east of the Whetstone mountains. Others disappear for miles, soon after the rains cease, and are only found flowing continuously at intervals. Among the latter is the Santa Cruz, which, rising in Arizona, runs south into Sonora, then turning west and north, returns to Arizona and empties into the Gila.

This river disappears near the line as it reenters Arizona and

reappears above Tubac, about twelve miles north of the line, and remains at the surface several miles, then it sinks out of sight and comes to the surface at a point about forty miles distant and about eight miles south of Tucson, not far from the old church of San Xavier, built over 100 years ago for the Papago Indians, upon the site of another that had stood 150 years. It now appears for about sixteen miles, and about eight miles north of Tucson again disappears for ninety miles, being found 150 feet below the surface about fifteen miles north of Tucson.

The reason of this eccentric action is found in the fact that the valley of the Santa Cruz, everywhere wide and quick sloping, is composed of coarse gravels, which being nearly destitute of clay, permits the water to seek a lower level until it flows along the bed rock. At Tubac and Tucson a series of trap dikes across the valley, nearly at right angles to the stream, making a natural dam that brings the water to the surface. This accounts for the fact that Tucson has been for years an oasis in the desert, and was a permanently settled town of Pima Indians, when first visited by Coronado in 1539.

Below Tucson, where the river commences to sink, the farmers dig long ditches, graded slightly as possible, and bring the water out of the lower country for quite a distance. Adopting this hint from nature, a number of California companies have secured good supplies by digging deep trenches across the narrow valleys or canyons to bed-rock, then building a tight wall of masonry therein, thus bringing the subterranean supply to the surface.

When I first went to Arizona, I found it to be the opinion of the settlers that water must be searched for by digging down to the underground stream in the middle of the valley, as was the custom and is now by the Mexicans.

Many fine grazing tracts were unoccupied for want of water, especially upon the foot hills, where the best gramma grass was found and generally much desired shade. Some one thought of testing the slope near the foot of the mountains, and plentiful supplies were thus found in many places, of course depending as every where else upon the water shed above.

The Southern Pacific Railroad Company have experimented with artesian wells and, while some have been failures, enough have been successful to warrant attempts all along the line.

The great Sulphur Spring Valley, sixty miles wide, and shunned

by prospectors and travelers on account of its dearth of water, has been found to have plenty of water almost everywhere, from 30 to 40 feet below the surface, and within a few years the great Pierce mine was found in this valley This mine was bought by Senator Penrose for $60,000, and is no producing $450,000 per month.

While developing some mining property west of Querobabi, on the Sonora railroad, and about ninety miles below the boundary line, I found an extreme scarcity of water. The mines were inside an elevated rim of low hills, some nine miles from the station, and about 500 feet higher.

The railroad was located at the lowest point of the wide valley and near a dry arroyo. The Mexicans had dug a well near the depot 300 feet deep, without getting water, and the attempt was abandoned. To supply their employees, the railroad company sent water in large iron tanks from a point some thirty miles distant. For some time I purchased from four to six barrels a day for camp use, paying two cents a gallon, and hauling all the way up hill to the camp over a sandy road. After some study of the surroundings, I determined to sink a well, although the Mexicans laughed at the idea. Selecting a point quite near the arroyo where it debouched from the circle of hills, I sunk a shaft four feet by five feet, blasting through porphyry all the way, until I reached a point ninety-two feet below the surface, when the water which had begun to come in at seventy feet in small quantities, now came in so fast I went no farther, and the next day we had ten feet of fine water. When the rainy season came my well had seventy-two feet of water in it and was the wonder of the Mexicans. The main road, in use for more than a century, was changed so that travelers could camp at my well, and "Allis Pozo" is in use today and the only well of its kind for hundreds of miles. I would say here that when the Mexicans dig such deep wells in the valleys as I have mentioned (and I have seen many from one to two hundred feet deep), the soil is so firm that no curbing is needed.

A rude windlass is erected over the well rigged with a grooved wheel about eighteen inches in diameter, made of wood, over which a raw hide rope is passed. At one end a bucket made of rawhide, holding about half as much as a flour barrel is fastened, and the other end tied around the horns of a steer, which thus makes a primitive hoisting machine, used also to hoist the water

when the well is completed. The Papago Indians who inhabit the driest portions of Arizona and Sonora have another way of procuring, or I might say, saving water on these arid plains. Selecting a place where the slope is pronounced, they dig long trenches or throw up a ridge of earth diverting from the lowest point at an angle of forty-five or sixty degrees. At the lowest point where the water is collected the earth is thrown up from both sides, making in some cases a dam four or five feet high. The inside is carefully plastered with wet adobe soil, making a small pond. The heavy rains (if they happen to have any that season) fill these ponds, and this supplies them sometimes until quite well along into the dry season. When this is exhausted they migrate as usual to springs in the mountains, known to them, where they remain until the next wet season. As the Indians and the herds use out of the same pond, no pains being taken to keep the cattle from wading in it, the condition of the water when nearly exhausted can better be imagined than described, and I am afraid would lead to a remonstrance from the Massachusetts Board of Health, if they ever saw it.

Myself and a companion, named John McDonald, once lost our way in the Papago country, while attempting to find a mine near the Mexican border. We were out of water and nearly choked, when at dark we stumbled on to one of these abandoned rancheros. By carefully exploring the deep holes in the clay, made by the feet of the cattle, we found about two quarts of water from a late shower. This we strained two or three times and made some coffee, putting in a good deal of sugar. It came the nearest to some of my war experiences in the swamps of North Carolina of anything I ever met since in the way of bad water. Our horses had to go without and we traveled twenty miles the next day before we found water.

Starting out one morning from Nacosari canyon, in eastern Sonora, and among the foot-hills of the Sierra Madre, a party of us searched for many miles for an old abandoned mine of the ancient days.

I carried a canteen holding two gallons of water, but by noon it was all gone, as I had a bad attack of fever and ague, and I had shared with another member of our party. The sun was blazing hot, and by 4 o'clock we were all out of water, and pretty well used up, and turned towards camp.

Crossing a steep, high hill, we saw in the valley two large, green trees said to be mountain mahogany. One of the Mexicans said we would surely find water there. Our mules seemed very willing to go all at once, and we soon reached the place. I found under the trees, which were near a high ledge of rock, two tanks as they are called, being deep holes in the rocks about four feet in diameter and nearly the same depth, which had been filled by the rains of many weeks previous. The top of the water was covered with a thick, green scum. On dipping this out, the water seemed alive with black bugs resembling our beetles. I slapped the surface with a quart cup which caused them to scuttle away, and taking a drink, I found the water perfectly pure, and it seemed to taste as well as any I ever drank. It was accidentally finding some tanks like these on the desert west of Tucson that saved the lives of the men under General Kearney, who marched from Santa Fe to Los Angeles at the time we first occupied California.

As I intimated when I began, I might tell you some experiences not exactly in the line of superintending water works, and if I have not already exhausted your patience, I will give you in closing an experience I had in looking up some curious rock sculpture, by some ancient dwellers in Sonora.

While engaged in opening the Sonora mines, I was also developing some property in the Sonoita valley, about twenty miles north of Nogales, a small town on the railroad, where it crosses the boundary line. Thus I was obliged to make frequent trips over this railroad, which connects Guaymas with Benson and Tucson, Arizona.

While in Tucson, on one of these trips, I met a gentleman who had been looking for coal in Sonora. He informed me that while examining the country southeast of Magdalena, he had came across what he called the "Indian rock sculpture," about sixteen miles distant. He described rooms cut in the rock, grapes in bunches carved on snow white walls and circular projections smoothly carved and beautiful to behold. All this so excited my curiosity that I determined to visit the place at the first opportunity.

This did not occur until March, 1883. I had met at Magdalena a Mr. Wells, who had accompanied my informant on his coal hunting expedition. I had arranged with him to be my guide whenever I could stop off, and on March 21 I left the mines at Querobabi, for the station, arriving there about dark. Before leaving camp, I

was informed that a large band of Apaches, lurking in the Sierra Madres, had made a descent near Carbo, a town some twenty miles south, and were driving off all the cattle they could gather. Some of my men were quite alarmed, and feared our camp might be attacked. I assured them that there was no danger, as I had never known the Apaches to cross the railroad, and we were nine miles west. On reaching the station I found a special train with Mr. Seeley, the superintendent, the chief engineer and Mr. Hunt, the paymaster, on their regular trip to pay off, and I went to Magdalena with them. Our train had barely left the station, when as I afterwards learned, several men bringing silver from the San Augustine mine, situated some twenty miles east, were fired upon by a party of Apaches, hidden in the bushes a mile from the station. The men reached the station, with no casualties except wounding one of the mules.

Arriving at Magdelena about 9 o'clock, I went to the hotel and there found Wells, and arranged for an early start. Daylight found us on our way each on a good horse and well armed. Our way for the first eight miles followed the road over a high and rugged mesa, covered by prickly pear and giant cactus. After leaving the valley, where the abundant streams of water had made the existence of a town possible, the country assumed a forbidding aspect. Sage brush, mesquite and an occasional palo verde were the only vegetation, while tall crosses or large heaps of stones marked no less than seven graves of travelers, killed by the Indians, within as many miles.

One of the saddest scenes in Arizona and Sonora is the solitary grave found here and there all over the country, marking the spot where some lonely traveler or wandering prospector has fallen a victim to the murderous Apache. In southern Arizona it is said over eight hundred such graves dot the wayside.

Eight miles from Magdalena we left the road, taking a blind trail for eight miles more, leading over low ranges and a rugged country almost destitute of vegetation, to our destination. We found ourselves about 11 o'clock in a wide, grassy valley, enclosed by high hills, behind which towered the Sierra Madres which form the backbone of Sonora. A small brook running down through the valley and the green grass bordering it looked very pleasant after the tedious ride of the forenoon.

Here we found the first carvings, which instead of having been made by Indians were unmistakably wind carvings. Some of them were so beautiful and curious that I was not surprised that they had been supposed to be of human origin. The view for a long distance up the wide valley was unobstructed, except by a few detached cliffs of white trachite. The upper surface of these cliffs was of a much harder texture than that immediately below, as if the surface of melted outflow had been hardened by the air, and some of the cliffs were harder clear through than others. The upper layers were of a brown color, while the portions below, which had been worked out by the wind was as white as snow. The texture of the underlying rocks in the softer cliffs was somewhat harder than chalk, while imbedded were thousands of sharp edged grains of quartz, which becoming loosened were blown about by the wind, adding their cutting qualities to the erosive action of the wind-borne dust.

In some of the cliffs the rock was cut out in a beautiful manner, leaving a projecting roof hollowed out and as smooth as if cut by a skillful artist. In others, hard, concretionary substances stood out in relief, resembling a bunch of grapes. These after awhile becoming detatched, fall to the bottom of the cliff, covering the ground. These concretions were flint like and round, varying in size from that of a bullet to that of a butternut, and so hard that when placed upon an anvil, a severe blow with a sledge would hardly crack them.

In one of the cliffs the projections had been taken advantage of by three herders from Magdalena, who were taking care of a bunch of cattle feeding in the valley. A wall of boulders was built under the edge of the projecting rock, making a comfortable room eight feet wide and high and about twenty feet long.* The shape of one of the larger cliffs, shown in plan and elevation, was such that a large and secure enclosure was made by putting up a pair of bars, and it was used as a corral for the cattle. We made some examinations and picked up a few of the "grapes" of stone already described, before dinner.

After feeding our horses and taking our lunch, I suggested that we climb to the top of the highest cliff, about 40 feet. This we

*Mr. Allis distributed drawings and sketches illustrating these wind carvings and cup-shaped carvings mentioned farther on.—Ed.

did, not without considerable effort. There we found on the hard surface of the smooth, gently rounded slopes and flat places, another and quite a different kind of carving, evidently made by human hands. To my companion, these were quite as new as to myself, and I can find no evidence that they were ever noticed earlier than at our visit.

These carvings were cup-shaped, with curious channels in some places taking the place of the cups. The channels were mostly about four inches deep, and about as wide, but a few were somewhat larger. As will be noticed on the larger sketch, the circular rows of holes were in some cases enclosed by the channels, in others the reverse, while still other designs are channels without the cups. These channels were generally V shaped, although some were hollowed out more like the letter U.

Near the upper left hand corner of the sketch are seen four projections of solid rock, standing nearly two feet above the level of the cliff, each with a deep, well-carved hole in the summit about eight inches in diameter and about the same in depth. These holes were black with age, apparently, though fire may have done this.

On a shelf or bench of rock and some four or five feet below the top of the cliff, on which the cups were carved, was found what seemed to be a cistern, about eight feet in diameter and about four feet in depth, cut beautifully round, reminding one of the pot holes found in the rocks below the water-falls of many of our New England rivers. That this was a cistern seemed to be indicated not only by its position and evident human workmanship, but also by a narrow channel cut from its edge at top to the edge of the cliff, so that if it filled with water it would flow to a second bench below, where again we found cup and other carving, one of which resembled a crescent. In the side of the upper bench above the cisterns were found five cavities hollowed out, some eighteen inches or two feet long and nearly as deep. These seemed to have been designed as places of deposit for small articles.

I was much puzzled to account for these carvings, and on my return to Tucson mentioned them to Dr. J. C. Handy. He had a short time previously received a book by Charles Rau, published by the Smithsonian Institute, in 1882, describing the cup-carvings of Europe and Asia, which he showed me, and I at once saw that the Sonora carvings were of the same character as those the book de-

scribed. These carvings are so similar to those found at the Temple of Chandelahar, India, that I think we may without mistake assign them to the same origin, namely, emblems of the Phallic worship of the ancient Aryans of India. No cup-carvings like those found in Europe and Asia, except the scrolls designated as type 7 in his book, seem to have been known to Rau, as existing in this country, and those found on a large boulder in Santa Barbara county, California, and the latter he called mortar cavities. Detached holes of the Santa Barbara character are common and generally supposed to be corn-mills or mortars, and are much larger than the cup-carvings, generally eight inches in diameter and as deep.

In southern Arizona, the Initial monument of the Barba-comori grant surveyed by myself in 1882, is built around a post set in one of these corn-mortars, found on the summit of a magnetic rock, on the edge of a cienaga at the center of the grant. I observed a row of these corn-mill holes under a large projecting rock, a few miles south of Tucson, Arizona, where evidently the families of the Indians collected in the shade to pound their corn. From this point a fine view was had of the valley of the Santa Cruz river. These holes were all large and in the hardest rock.

The conclusion as indicated, if correct, throws another ray of light upon the vexed question of who first settled the Western Hemisphere, and points to a race far antedating the Aztecs or Toltecs. whom Cortez found already an ancient race of people in Mexico.

We were fortunate in selecting the day of our visit, for on the day following the same band of Apaches, spoken of as being at Querobabi, reached this place and the three herders were all killed, as was also the owner of the cattle, who, unfortunately, went there the same day.

FIRE PROTECTION, BY WHOM AND HOW IT SHOULD BE PAID?*

BY JOEL FOSTER, SUPERINTENDENT, MONTPELIER, VT.

If a private corporation owns the franchise of a water system in a village or city, it is universally understood at the outset that the village or city is to pay a stipulated price for hydrants, watering troughs, stand pipes for sprinkling streets, flushing sewers and for public buildings. These expenses would be paid by an increase tax on the grand list, and who claims that it would not be just and right?

On the other hand, the village or city owns its water system. Is there any reason why an appropriation from that village or city, equal to the sum paid to the private company for the same benefits received, should not be made? On a careful investigation of this question I believe that every considerate person would answer, No.

It is universally conceded by all engineers and contractors of water works that the cost to construct for a good fire protection is fully one-third more than is necessary for domestic and sanitary purposes. Then why not have the property protected bear its due proportion of the burden of expense, instead of wringing it out of the patrons of the city water? We often hear the remark, "The water works will pay for themselves; why make the appropriation? It is only taking money from one pocket and putting it into the other." Is this assertion true?

In making no appropriation for the hydrants and other public uses, and relying wholly on the domestic and business receipts of the water works to pay their cost and expenses, who pays for fire protection and the other luxuries named? I will try to give figures below that will demonstrate the facts.

---

*From the Annual Report, Montpelier, Vt., Feb., 1898.

There was printed in the city papers last year a statement giving the total grand list of the city in 1897 ($38,004.89), and the lists of individuals.

The grand list of taxpayers having a list of $100 and over aggregated	$16,096.10
Over $50 and under $100	6,982.15
Less than $50	14,926.64
The water receipts for the business year were	11,313.86
Of this sum I find that the division of the taxpayers having a grand list of $16,096.10, paid for water service	2.820.00
The second division, $6,982.15, paid for water service	1,676.50
The third division, $14,926.64, paid for water service	6,817.36

To tax these several divisions of the grand list, as shown above, on the basis of their contributions to the gross water receipts ($11,-313.00), the percentage assessed to each division would be as follows:

Taxpayers having a grand list exceeding $100	$0.175	on the	dollar
Taxpayers having $50 and less than $100	.24	"	"
Taxpayers having less than $50	.45	"	"

which shows at a glance the unjust discrimination of the taxation to the varied owners of city property.

To illustrate further the inequality of paying for fire protection and other public uses of city water by throwing the whole burden of such expenses on to private consumers of water, I will take the case of individuals.

The water system asks the city of Montpelier to appropriate $2,300.00 a year for hydrants, watering troughs, stand pipes, etc.

This sum was voted at the annual village meeting December 5, 1887, and was paid over to the water system annually till 1896. The city council then refused to make the appropriation, compelling

the private users of the city water to bear the entire expense for public uses.

Under this new policy, I find by computation that the percentage paid by the division of taxpayers, whose grand list is $16,096, is 3.6 per cent., or.................. ....$	579.45
That those whose grand list aggregates $6,982, is 5 per cent., or......	349.10
That those whose grand list aggregates $14,-926, is 9.15 per cent., or...	1,365.73
Loss by omitting fractions..........	5.72
	$ 2,300.00

That is, the division of taxpayers whose grand list is $100 or over pays for fire protection 3.6 per cent. of their grand list.

Those whose grand list is less than $100 and over $50 pay 5 per cent. of their grand list.

Those whose grand list is $50 and under pay 9.15 per cent. of their grand list.

This is a very unequal taxation.

The inequality of taxation for fire protection under the new policy of the city is further shown thus:

Mr. A. has a grand list of $200, pays $12 water tax.

Mr. B. has a grand list of $20, pays $12 water tax.

By this showing Mr. A., with his grand list of $200, contributes no more to the general receipts than Mr. B., with only a $20 grand list.

Is there any reason or justice in this division? Why should not Mr. A., with his $200 grand list, pay more for his fire protection than Mr. B., with only a grand list of $20?

The conclusion of the whole matter is, that putting the estimated cost of water for fire protection and other public uses into the regular expenses of the city, to be paid, like every other expense, on the grand list, is the only way to equalize taxation for the purposes named.

STATISTICS

FOR THE YEARS

1895 and 1896.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

Compiled by the Editors.

1895—I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Con'uction.	By whom Owned.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per Ct. Ashes.	Price per Ton of 2240 Lbs.
1	Attleboro, Mass...	1873	Town.	Well near Seven Mile River.	Pump to S. P.	Blake & Deane.	Bituminous.		$4.60
2	Bay City, Mich....	1872	City.	Lake Huron.	Direct Pumping.	Holly.	Bituminous.		
3	Brockton, Mass....	1880	City.	Storage Reservoir	Pump to S. P.	Worthington.	Bituminous.	8.44	4.74
4	Burlington, Vt.....	1867-8	City.	Lake Champlain.	Pumping.	Worthington.	Anth. Mill S.		4.65-4.78
5	Concord, N. H	1872	City.	Penacook Lake.	Gravity and Pump to R.				
6	Fall River, Mass .	1874	City.	Watuppa Lake.	Pump to S. P. and Tanks.	Worthington & Davidson.	Bituminous.		
7	Fitchburg, Mass...	1871-2	City.	Storage Reservoirs.	Gravitation.				
8	Lynn, Mass......	1872	City.	Storage Reservoirs.	Pump to R.	Morris & Loretz.	Bituminous.		4.55-4.62
9	Middleboro, Mass.	1885	F. Dist	Large Well.	Pump to S. P.	Deane.	Bituminous.		4.75-4.50
10	New Bedford, Mass	1866-69	City.	Storage Reservoir.	Gravity and Pumped to R.	Quintard and Worthington	Bit. & Anthracite.	12.16	4.20-4.50 4.12-4.19
11	New London, Conn	1872	City.	Lake Konomoc.	Gravity and Pump to T.	(Water Motor.)			
12	Newton, Mass	1876	City.	Filter Basin and Driven Wells.	Pump to R.	Blake & Worthington.	Bituminous.	6.00	4.15
13	Oberlin, Ohio.....	1887	Vil'ge.	Vermillion River.	Pump to S. P.	Deane.	Bituminous.		2.24-2.35
14	Plymouth, Mass...	1855	Town.	Great and Little South and Lout Ponds.	Gravity and P.	Worthington.	Bituminous.		4.25
15	Reading, Mass...	1890-1	Town.	Filter Gallery	Pump to S. P.	Geo. F. Blake.	Bituminous.		5.00-4.90
16	Springfield, Mass..	1873-5	City.	Impounding Reservoirs.	Gravitation.				
17	Taunton, Mass....	1876	City.	Elders Pond.	Gravity and D. Pumping.	Holly & Allis.	Bituminous.	3-7	3.60-4.00
18	Waltham, Mass....	1895	City.	Filter Basin.	Pump to R.	Worthington.	Bituminous.	11.00	
19	Woonsocket, R. I.	1884	City.	Crooks Falls Brook	Pump to R.	Worthing'n & Deane	Bituminous.	6.32	4.35
20	Yonkers, N. Y....	1874	City.	Grassy Sprain Brook.	Pump to R. & S. P	Wright & Worthington.	Anthracite.	12.25	4.34

1895—I. GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, Lbs.	4. Lbs. of Wood. 3.	5. Total Fuel Consumed for the Ye'r Lbs.	6. T'l Pump'ge for the Year in Gallons.	7. Av'ge Static Head ag'st Pumps.	8. Av. Dy'mic Head ag'st Pumps, ft.	9. No. Gallons Pumped Per Lb. of Coal.	10. Duty in Ft. Lbs. Per 100 lbs. of Coal, No Deductions.	11. Cost per Mil'on Gal. Pumped into Res'voir Fig. on Pmp. Station Ex's.	12. Cost per Mil. Gals. Rai'd 1 ft. High. Fig. P. Sta. Ex	13. C'st pr Mil. Gals. P'm'd into Res'vr Fig on To'l Main'ance	14. C'st pr Mil Gal. r'sd 1 ft high Fig on Total main'ance
1	465,993	1,000	466,993	109,808,840	160	175&188	236	36,900,000	$17.40	.0927	153.50	.817
2	3,220,140	49,329	3,269,469	1,122.363,460		113			6.73	.0595	43.82	.3871
3	505,185	225	505,410	400,974,405		43	793.7	28,451,641	7.40	.172	87.60	2.03
4				324,158,575	289	316			27.50	.087	141.53	.447
6	3,769,920			1,155,775,756		186			11.66		119.67	
8	436,500 1,723,799	222	436,500 1,724,465	344,707,090 1,251,053,100		160.68 160.47	789.7 725.5	105,826,355 97,091,511	5.88	3.66	76.65	.477
9	456,580		456,580	77,833,000	180	201	170.58	28,571,637	34.93	.174	89.47	.445
10	2,373,000	371	2,373,371	1,707,559,266	125.4 125.1 to 125.6	127.7 126.4 to 134.9	658 520 807	74,007,887 54,770,422 85,972,256	6.93	.530	40.93	$.31\frac{34}{100}$
12	1,813,900	10,000	1,823,900	662,307,000	234	258	363	107,000,000	10.10	.039	156.3	.61
13	298,930		298,930	27,998,000	80	80	93.7	6,249,000	43.97	.55	164.20	2.05
14	2,181,600		2,181,600	103,118,400	65	66	471.72	25,965,355	14 55	.223	90.97	1.38
15	388,023		388,023	72,375,448	219	240	186.7	37,592,023	35.50	.147	178.51	.743
17	1,029,650		1,029,650	419,162,504		77.4	586.16	37,837,519	12.04	.155	163.55	2.11
18	1,648,900		1,648,900	445,972,320	164	190	271	43,084,870	19.92	.105	101.36	.53
19	872,477	317	872,787	225,587,860	238.4	239.5	258	52,248,733	15.15	.063	126.82	.53
20			4,230.266	1,166,751,521	185		276		11.38			

1895.—II.—FINANCIAL.

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
		$	$	$	$	$
1	Attleboro, Mass			14,188.00		
2	Bay City, Mich	17,514.55	4,891.76	22,406.31	413.99	22,820.30
3	Brockton, Mass			43,768.26	100.00	43,868.26
4	Burlington, Vt	34,161.77	5,431.62	39,593.39	3,161.57	42,754.96
5	Concord, N. H			55,239.77		
6	Fall River, Mass			117,130.47	326.00	117.456.47
7	Fitchburg, Mass	46,214.36	14,334.33	60,548.69		
8	Lynn, Mass	135,906.71	44,306.80	180,213,51	5,359.37	185,572.88
9	Middleboro, Mass	7,451.80	3,204.14	10,655.94	40.92	10,696.86
10	New Bedford, Mass	79,148.69	7,001.36	86,150.05	120.00	86,270 05
11	New London, Conn			38,634.05		38,634.05
12	Newton, Mass	74,149.31	7,800.00	81,949.31	4,016.08	85,965.39
13	Oberlin, Ohio	3,408.52	435.45	3,843.97	167.00	4,010.97
14	Plymouth, Mass	17,038.44	676.00	17,714.44	519,86	18,234.30
15	Reading, Mass	6,575.39	121.98	6,697.37	103.99	6,801.36
16	Springfield, Mass			173,840.65	33,448.40	207,289.05
17	Taunton, Mass	37,251.47	11,770.09	49,021.56	432.10	49,453.66
18	Waltham, Mass	49,870.21	5,667.16	55,537.37	4,531.35	
19	Woonsocket, R. I	26,868.02	7,562.38	34,430.40	101.21	34,531.61
20	Yonkers, N. Y	76,504.46	30,661.15	107,165.71	3,659.05	110,824.76

1895.—II.—FINANCIAL.—Continued.

Number.	Receipts from Public Funds. F Hydrants.	G Fountains.	H Street Watering.	I Public Buildings.	J General Appropriation or Miscellaneous.	K Gross Receipts.	AA Management and Repairs.	BB Interest on Bonds.	Miscellaneous Expenses.	Total Maintenance.
1	6,800	300.00		$ 225.00	$ 7,325.00	$ 21,513.00	$ 6,434.28	$ 10,400.00	$	$ 16,834.28
2					27,110.00	49,930.30	22,067.64	27,110.00		49,177.64
3	3,000.00					46,868.26	8,826.30	26,300.00		35,126.30
4	6,140.00		1,509.00	270.00	500.00	51,173.96	34,503,43	11,375.00		45,878.43
5					530.76	55,570.53	3,445.85	27,150.00		30,595.85
6					35,000.00	152,456.47	50,147.83	100,704.99		150,852.82
7							18,298.58			33,693.36
8						185,572.88	51,147.43	71,182.67		122,330.10
9						12,696.86	4,189,14	2,774.50		4,189.14
10					25,600.00	111,870.05	34,295.39	35,600.00		69,895.39
11					24,540.00	63,174.05	6,709 22	24,540.00		31,249.22
12	14,600.00	991.60	2,550.00	983.40	995.00	106,085.39	16,020.25	87,500.00	4,148.28	107,668.53
13					2,873,23	6,884.20	1,897.15	2,700.45		4,597.60
14						18,234.30	5,105,59	4,276.00		5,105.59
15	3,300.00				3,900.00	14,001.36	4,919.74	8,000.00		4.919,74
16	15,860.00	1,850.75	4,580.50	3,910.30	25.000.00	259,405.60	18,478.33	97,750.00	3,552.18	119,971.67
17	3.500.00	2,063.89	800,00	521.73		75,076.00	20,550.06	48,003.00		68,553.06
18						59,968.72	29,119.70	16,186.65		45,306,35
19	14,372,50	1,205.70	1,873.80	919.87	10,447,68	63,351.16	10,554.95	18,054.90		28,609.85
20	16,290.00				2,636.07	127,114.76	34,763.60	71,083.33	6,968.37	112,815.30

1895.—III.—CONSUMPTION.

Number.	Name of City or Town.	1	2	3	5	6	Percentage of Total Consumption Metered.	7	8	9	10
		Estimated Population.			Quantity used through Domestic Meters—Gals.	Quantity used through Man'f'tring Meters—Gals.		Average Daily Consumption, Gallons.	Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at date.					Each Inhabitant.	Each Consumer.	Each Tap.
1	Attleboro, Mass.....	8,300	6,800	6,300	109,808,840			306,357	36.2	48.7	
2	Bay City, Mich.....	33,000	20,000	14,000	53,088,095	51,033,957		3,074,968	93.0	219.0	1,661.0
3	Brockton, Mass.....	33,665	30,500	29,200	87,832,298	28,974,855		1,098,560	32.6	37.6	258.8
4	Burlington, Vt......	16,700	16,300	16,100	87,170,932	32,469,615	36.8	888,083	53.0	55.0	299.0
6	Fall River, Mass....	89,203		86,076				3,166,509	35.5	36.8	
7	Fitchburg, Mass....	26,500	23,000	20,300	58,157,000	286,000,000			94.0	123.0	670.0
8	Lynn, Mass.	66,861			215,591,850			4,360,142		67.5	
9	Middleboro, Mass...	Town, 7,000 Fire D. 4,200	4,000	3,700				213,378	51.0	57.7	306.0
10	New Bedford Mass..	56,300	47,076	46,154	18,533,073	251,346,482	16.0	4,711,866	84.0	102.0	587.0
11	New London, Conn.	15,000	14,700	14,000	14,000,000			1,244,320	83.0	89.0	467.3
12	Newton, Mass.......	28,500	28,100	27,900	235,000,000	110,000,000	52.0	1,801,162	63.2	64.2	304.0
13	Oberlin, Ohio.......	4,500	3,500	1,900	4,361,070	2,157,000	23.3	76,700	17.0	40.0	173.0
15	Reading, Mass......	4,717	4,140	3,550	4,179,920	583,414		198,289	42.03	55.85	263.33
16	Springfield, Mass...	51,534	47,000	41,000	355,608,935		21.0	4,638,060	90.0	113.0	587.0
17	Taunton, Mass.....	27,093	23,700	23,600	57,349,979	123,188,567		1,148,390	42.0	49.0	299.0
18	Waltham, Mass.. ..	21,000	20,400	20,000	28,120,950				58.5	61.9	102.0
19	Woonsocket, R. I...	28,500	26,000	23,500				621,464	21.8	26.4	336.0
20	Yonkers, N. Y.......	38,000	33,000	32,000	227,754,974	432,882,912	58.2	3,108,400	82.0	94.0	850.0

1895.—IV.—DISTRIBUTION.—MAIN PIPES.

		1	2	3	4	5	6	7	8	9	10	11	12	15
Number.	Name of City or Town.	Kind of Pipe.	Size of Distribution Pipe in Inches.	Length Extended During Year, Feet.	Length Discontinued During Year, Feet.	Total Length in Use, Miles.	Cost of Repairs Per Mile.	Number of Leaks Per Mile.	Length of Pipe Less than 4" Diameter, Miles.	Hydrants. No. Added.	Hydrants. Total in Use.	Stop Cocks. No. Added.	Stop Cocks. Total in Use.	Range of Pressure Pounds.
1	Attleboro, Mass...	C. I. & C. L.	4 to 16	1,660		28.60	$	0.14		2	223			50 to 62
2	Bay City, Mich....	C. I. & Wyckoff.	3 to 20	9,475	3,325	44.	16.01	1.	.06	17	387	23	670	35 to 38
3	Brockton, Mass...	W. I., C. L. & C. I.	6 to 30	24,108	1,210	54.5	4.58	.89		39	488	79	540	47 to 56
4	Burlington, Vt ...	C. L., W. I. & C. I.	4 to 24	7,433	3,515	35.65	30.	1.4	2.8	8	195	38	486	70 to 85
5	Concord, N. H ..			8,798		56.3				4	243	19	682	
6	Fall River, Mass..	C. I.	6 to 24			76.1				37	780	28	776	80
7	Fitchburg. Mass ..	W. I., C. L. & C. I.	2 to 30	10,938		59.34	6.78	.28	1.54	19	408	13	442	155 to 160 75 to 80
8	Lynn, Mass.......	W. I., C. L. & C. I.	2 to 20	6,304		124.		1.3		3	786	11	931	50 to 65
9	Middleboro, Mass.	C. I.	4 to 12	2,075		14.				3	102	10	140	45 to 60
10	New Bedford, Mass	W. I. C. L. & C. I.	4 to 30	31,080	22,453	76.3	13.88		1.1	17	624	29	864	29 to 38
11	N. London, Conn.	W. I., C. L. & C. I.	4 to 20	7,858		43.1	10.60	.7	2.9	5	198	8	227	45 to 50
12	Newton, Mass ..	C. I.	4 to 20	34,576		120.	15.23	.09	2.8	45	805	41	643	84
13	Oberlin, Ohio.....	C. I.	4 to 12	1,121		7.8	1.40	.25	.3	2	72	1	45	27 to 32
14	Plymouth, Mass..	W. I. & C. L.	2 to 20	4,879½		34.	5.30	.1	10.5	1	106	5	312	
15	Reading, Mass....	C. I.	4 to 12	1,976		20.4	none	none	none	3	111	3	193	68 to 78
16	Springfield, Mass.	W. I., C. L. & C. I.	¾ to 36	39,194	5,182	123.6	6.03	.41	7.9	76	793	133	1,440	100 to 120 30 to 35
17	Taunton, Mass ...	C. I.	4 to 20	1,393		70.7	25.33		1.2	24	705	14	480	45 to 50
18	Waltham, Mass...	C. I. & C. L.	2 to 24	3,010		47.8	8 10	.5		10	281	17	602	56
19	Woonsocket, R. I.	C. I.	4 to 20	3,690		37.	2.92	.43	0	5	462	10	397	90 to 115
20	Yonkers, N. Y. . .	C. I.	4 to 30	36,406		56.7	26.00	1.5	0	59	582	35	364	

1895.—V.—DISTRIBUTION—SERVICE PIPES.

		16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
Number.	Name of City or Town.	Kind of Pipe.	Size of Pipe in Inches.	Length Extended Feet.	Length Discontinued Feet.	Length in Use. Miles.	No. Added.	Total in Use.	Av. Length of Service.	Av. Cost of Service.	Number added.	Now in Use. Domestic.	Now in Use. Manu-fac'ing.	No. added.	Total in Use.
1	Attleboro, Mass...									$	20	619			1
2	Bay City, Mich....	Lead, W. I. & Wyckoff.	$\frac{3}{8}$ to 8				14	1,851			43	559			
3	Brockton, Mass....	W. I., L. L., C. L & C. I.	$\frac{3}{4}$ to 6	16,640	263.	20.7	371	4,245	43.3	8.32	485	2,963			
4	Burlington, Vt ..	Gal. I. and Lead.	$\frac{1}{2}$ to 6	3,739	56.	16.	134	2,969	27.9	9.00	179	1,186	75	3	29
5	Concord, N. H....			2,185		13.5		3,055							
6	Fall River, Mass...	Lead.	$\frac{1}{2}$ to 2				308	6,372			325	5,212			
7	Fitchburg, Mass...	W. I., C. L. & C. I.	$\frac{3}{4}$ to 8	6,338		42.8	140	3,876	58.0	14.06	231	1,652	126	11	66
8	Lynn, Mass.......	W. I., C. L., Gal., Ada.	$\frac{3}{4}$ to 10	14,204	3,850.	89.	279	11,023			316	1,206			
9	Middleboro, Mass.	L., W. I. lined with C.	$\frac{3}{4}$ to 2	1,431		7.8	27	697	55.0		17	240	16	0	5
10	New Bedford, Mass	Lead and Cast Iron.	$\frac{1}{2}$ to 8	11,043	324.	50.16	260	8,027	42.0	10.52	33	196	58	11	79
11	New London, Ct. .	W. I., C. L., G., L., C. I.	$\frac{1}{2}$ to 4	2,408		9.7	108	2,663	22.3	10.85	9	167			22
12	Newton, Mass. ..	Lead, W. I. and C. I.	$\frac{1}{2}$ to 6	22,490	4,250.	67.8	332	5,917	62.0	12.90	400	4,557	23		16
13	Oberlin, Ohio......	Gal. and Lead.	$\frac{3}{4}$ to 1				44	443	25.0	8.00	35	127	10	0	0
14	Plymouth, Mass...	Lead and Cem't Lined.	$\frac{1}{2}$ to 1	192		$5\frac{1}{2}$	43	1,620	$17\frac{2}{3}$	3.04					1
15	Reading, Mass ..	G. I., C. L , L. L. & C. I.	$\frac{3}{4}$ to 6	4,943	none	9.3	69	753	71.0	30.83	45	87		2	4
16	Springfield, Mass..	W. I. and C. I.	$\frac{1}{2}$ to 6				418	7,900			260	2,207		18	162
17	Taunton, Mass ...	Cem't L. and W. I.	$\frac{3}{4}$ to 3		5,352.76	37.1	95	3,843		18.68	56	1,228	138	1	14
18	Waltham, Mass....	C. I. & W. C. L.	$\frac{3}{4}$ to 6	3,485	75.	33.8	43	3,035	72.4	36.85	0	72		0	6
19	Woonsocket, R. I.	Lead and Iron.	$\frac{5}{8}$ to 6	1,749			93	1,760	18.6	11.43	84	1,469	42		6
20	Yonkers, N. Y....	Lead and C. I.	$\frac{3}{8}$ to 8				210	3,650			224	3,590	116	1	9

STATISTICS FOR 1896.

1896—I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Con'uction.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per Ct. Ashes.	Price per Ton of 2240 Lbs.
1	Attleboro, Mass.....	1873	Circular Well near River.	Pump to S. P.	Blake & Deane.	Bituminous.		$4.60
2	Bay City, Mich......	1872	Lake Huron.	Pump Direct	Holly.	Coal Slack.	8.76	4.77
3	Brockton, Mass......	1880	Storage Reservoir	Pump to S. P.	Worthing'n & Holly.	Bituminous.		
4	Burlington, Vt.......	1867-8	Lake Champlain.	Pumping.	Worthington.	Anthracite.		4.65-5.10-5.35
5	Fitchburg, Mass.....		Storage Reservoirs.	Gravitation.				
6	Lynn, Mass.........	187 0	Storage Reservoirs.	Pump to R.	Leavitt & Loretz.	Bituminous.		4.14
7	Middleboro, Mass...	1885	Large Well.	Pump to S. P.	Deane.	Bituminous.		4.50
8	New Bedford, Mass..	1866-9	Storage Reservoir.	Gravity and Pump.	McAlpine & Worthington	Bituminous.	8½	4.00
9	New London, Conn..	1872	Storage Reservoir.	Grav. & Pump by Water Motor	(Lang & Goodhue)			
10	Newton, Mass.......	1876	Filter Basin Springs & Wells.	Pump to R.	Blake & Worthington.	Bituminous.	6.00	4.18
11	Oberlin, Ohio.......	1887	Vermillion River.	Pump to S. P.	Deane.	Bituminous.		2.25
12	Plymouth, Mass.....	1855	Great and Little South and Lout Ponds.	Gravity and P.	Worthington.	Bituminous.		4.75
13	Reading, Mass......	1890	Filter Gallery.	Pump to S. P.	Blake.	Bituminous.		4.80 4.90
14	Springfield, Mass..	1864- 1873-75	Reservoirs.	Gravitation.				
15	Taunton, Mass......	1876	Elders Pond.	Gravity and Pump.	Holly & Allis.	Bituminous.		3.85
16	Waltham, Mass......	1872	Charles River.	Pump to R.	Worthington.	Bituminous.	11.00	4.28
17	Woonsocket, R. I...	1884	Crooks Falls Brook	Pump to Tanks.	Worthington.	Bituminous.	7.00	4.38
18	Yonkers, N. Y......	1874	Storage Reservoir.	Pump to R. & Tank	Wright & Worthington.	Ant'racite & Bit.	10.5	4.13

1896—I. GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, Lbs.	4. Lbs. of Wood. 3.	5. Total Fuel Consumed for the Ye'r Lbs.	6. T'l Pump'ge for the Year in Gallons.	7. Av'ge Static Head ag'st Pumps.	8. Av. Dy'mic Head ag'st Pumps, ft.	9. No. Gallons Pumped Per Lb. of Coal.	10. Duty in Ft. Lbs. Per 100 lbs. of Coal, No Deductions.	11. Cost per Mil'on Gal. Pumped into Res'voir Fig. on Pmp. Station Ex's.	12. Cost per Mil. Gals. Rai'd 1 ft. High. Fig. P. Sta. Ex	13. C'st pr Mil. Gals. P'm'd into Res'vr Fig on To'l Main'ance	14. C'st pr'Mil Gal. r'sd 1 ft high Fig on Total main'ance
1	455,881	1,000	456,881	115,559,540	160	B175 D188	253	39,750,000	$18.70	$ .0996	$ 143.50	$ .765
2	3,535,760			1,909,523,471		113			7.29	.064	44.42	0.393
3	491,275			397,982,808		43	810.10		5.08	.118	96.00	2.23
4				305,817,025	289	316			34.59	0.109	172.19	0.535
5												
6	1,146,050 1,598,500	300 600	1,146,350 1,599,100	623,382,276 1,037,462,650		162.3 165.25	543.9 648.7	73,607,452 89,426,269	6.55	.0399	79.06	.4816
7	473,270		473,270	77,252,570	180	201	165.55	28,199,725	32.11	.16	89.61	.445
8	2,884,200	473	2,884,673	1,975,205,472	125.7 141.5 124.9	135.6 151.52 129.51	642 785 435	72,355,552 54,999,360 84,774,912	5.72	4.29	38.72	29.04
9												
10	1,584,800	8,000	1,592,800	666,259,000	234	254	418	111,000,000	12.62	.05	160.84	.63
11	290,000		290,000	24,584,700	80	80	84.8	5,656,000	49.00	.61	190.80	2.38
12	228,100		228,100	105,399,360	66		462.07	25,434,181	15.41	0.2323	90.42	1.37
13	524,703		524,703	72,734,860	219	240	139	3,177,050	43 59	.181	186.78	.778
14 15	1,011,900		1,011,900	427,437,849		69.83	602.36	34,096,561	10.94	.1567	166.55	2.39
16	2,065,000			555,213,476	165	186	270	42,810,750	12.00	.063	69.15 101.36	.0304
17	953,000	258	953,774	259,015,107	238	239	271	54,198,946	14.90	.062	117.28	.48
18	4,309,543			1,243,182,067	185		288.4		11.00			

1896.—II.—FINANCIAL.

Number.	Name of City or Town.	Receip's from Consumers. A Rates Domestic.	B Rates Manufacturing.	C Net Receipts for Water.	D Miscellaneous Receipts.	E Total Receipts.
1	Attleboro, Mass	$	$	$ 15,292.29	$	$
2	Bay City, Mich	17,322.88	5,741.98	23,064.86	159.10	22,223.96
3	Brockton, Mass	40,333.16	9,174.69	49,507.85	183.04	49,690.89
4	Burlington, Vt	36,513.32	4,621.78	41,135.10	1,896.08	43,031.18
5	Fitchburg, Mass	51,204.66	13,968.33	65,172.39		
6	Lynn, Mass	128,047.11	48,768.51	176,815.62	9,357.83	186.173.45
7	Middleboro, Mass	7,751.65	2,741.65	10,439.30	76.79	10,570.09
8	New Bedford, Mass	85,866.74	8,290.33	94,157.07	103.00	94,260.07
9	New London, Conn			41,104.39		41,104.39
10	Newton, Mass	78,958.71	5,300.00	96,641.98		
11	Oberlin, Ohio	3,584.21	380.00	3,964.21	644.96	4,609.17
12	Plymouth, Mass	15,455.17	1,397.25	16,852.42	235.29	17,087.71
13	Reading, Mass	7,346.24	137.75	7,483.99	70.31	7,554.30
14	Springfield, Mass	129,175.52	55,222.65	184,398.17	24,148 39	208,546.56
15	Taunton, Mass	38,541.69	10,836.86	49,378.55	310.12	49,688.67
16	Waltham, Mass	52,395.11	6,504.16		1,605.28	60,504.55
17	Woonsocket, R. I	29.373.13	7,834.38	37,207.51	101.21	37,308.72
18	Yonkers, N. Y	83,019.73	26,757.39		5,009.91	

1896.—II.—FINANCIAL.—Continued.

Number.	Receipts from Public Funds.					K	AA	BB		
	F	G	H	I	J					
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.	Miscellaneous Expenses.	Total Maintenance.
1	$ 6,488.00	$ 375.00	$	$ 287.00		$ 22,484.23	$ 4,552.10	$ 10,984.03	$ 982.58	$ 16,518.71
2					$ 26,110.00	49,333.96	18,731.58	26,110.00		44,841.58
3	3,000.00					52,690.89	8,736.39	29,725.00		38,461.39
4	3,360.00		1,889.91	6,069.91	3,557.07	52,658.16	42,008,16	10,650.00		52,658.16
5							14,740.00			40,530.33
6							58,005.82	73,346.24		131,352.06
7					2,000.00	12,570.09	4,222.44	2,700.00		4,222.44
8					46,883.33	141,143.40	29,588.85	46,883.33		76,472.18
9					24,540.00	41,104.39	5,712.52	24,540.00		30,252.52
10	15,200 00	130.00	2,700.00	950.00	120.00	116,605.98	17,271 52	89,900.00		17,271.52
11					2,700,00	7,309.17	2,092 70	2,600.00		4,692.70
12						17,087.71	5,466.07	4,065.60		9,531.67
13	3,330.00				4,570.00	15,454.30	5,617.21	7,968.53		13.585,74
14	16,820.00	1,491.80	4,975.58	4,073.95	25.000.00	261,822.89	21,022.95	96,000.00		124,660.15
15	3.500.00	1,794.79	800,00	532.06		76,897.15	21,292.01	49,893.00		71,185.01
16						60,504.55	21,872.80	16,520.00		38,392.80
17	41,642.50	1,467.26	2,096.26	851.16	11,000,00	67,365.90	11,124.39	19,254.71		30,379,10
18	18,210.00				2,035 53	135,032.56	37,067.02	73,950.00	21,828.03	

1896.—III.—CONSUMPTION.

Number.	Name of City or Town.	1 Estimated Population. Total at Date.	2 Estimated Population. On Line of Pipe.	3 Estimated Population. Supplied at date.	5 Quantity used through Domestic Meters—Gals.	6 Quantity used through Man'f'tring Meters—Gals.	Percentage of Total Consumption Metered.	7 Average Daily Consumption, Gallons.	8 Gallons per Day. Each Inhabitant.	9 Gallons per Day. Each Consumer.	10 Gallons per Day. Each Tap.
1	Attleboro, Mass.....	8,500	7,000	6,500	115,559,540			315,612	37.1		48.5
2	Bay City, Mich.....	33,000	20,000	14,000	53,762,412	52,977,831	10.57	2,758,261	83.0	197.0	1,484.0
3	Brockton, Mass.....	35,000	32,000	31,000	116,536,470	40,604,662		1,087,111	31.06	34.90	239.80
4	Burlington, Vt......	17,300	16,900	16,700	107,786,961	18,291,510		835,565	48.0	50.0	272.0
5	Fitchburg, Mass....	26,500	23,000	20,300	56,900,000	279,000,000			94.0	123.0	670.0
6	Lynn, Mass.........	69,361		67,139	249,906,830			4,551,789		67.8	
7	Middleboro, Mass...	Fire D. 4,200 7,000	4,000	3,700					50.25	57.0	292.0
8	New Bedford Mass..	59,000	49,530	45,570	40,475,088	316,760,610		5,259,017	89.0	108.0	623.0
9	New London, Conn.	15,500	15,000	14,500				1,385,134	89.0	95.5	505.0
10	Newton, Mass.......	29,500	29,100	28,900	275,000,000	55,000,000		1,812,484	614.10	627.10	289.0
11	Oberlin, Ohio.......	4,600	3,500	2,000	6,000,000	1,900,000	33.0	67,200	14.6	33.6	143.0
12	Plymouth, Mass....										
13	Reading, Mass......	4,750	4,160	3,600	5,545,170	1,031,483		199,273	41.95	47.89	245.41
14	Springfield, Mass...	54,812	48,800	42,500	372,253,326		21.0	4,819,828	88.0	113.0	581.0
15	Taunton, Mass......	27,093	26,700	26,361	51,276,720	92,735,534		1,167,863	43.0	44.0	296.0
16	Waltham, Mass.....	21,500	21,000	20,500	33,441,260			1,521,133	70.0	72.0	490.0
17	Woonsocket, R. I...	28,500	26,500	26,500				708,227	24.9	26.7	359.0
18	Yonkers, N. Y.......	40,000	34,000	33,000	248,223,254	365,141,844	50.3	3,331,802	83.0	100.0	910.0

1896.—IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Distribution Pipe in Inches.	3 Length Extended During Year, Feet.	4 Length Discontinued During Year, Feet.	5 Total Length in Use, Miles.	6 Cost of Repairs Per Mile.	7 Number of Leaks Per Mile.	8 Length of Pipe Less than 4" Diameter, Miles.	9 Hydrants. No. Added.	10 Hydrants. Total in Use.	11 Stop Cocks. No. Added.	12 Stop Cocks. Total in Use.	15 Range of Pressure Pounds.
1	Attleboro, Mass.	C. I. & C. L.	4 to 16	5,210		29.58	$	0.13		11	234			50 to 62
2	Bay City, Mich.	C. I. & Wyckoff.	3 to 20	2,554	6,830	43.25	13.63	1.	.06	6	393		662	35 to 38
3	Brockton, Mass.	W. I., C. L. & C. I.	6 to 30	14,714.3	25	56.84	3.26	.56		31	519	36	576	47 to 56
4	Burlington, Vt.	C. L., C. I. & W. I.	4 to 24	9,992	8,051	36.	9.	.75	14.619	7	202	27	513	70 to 85
5	Fitchburg, Mass.	W. I., C. L. & C. I.	2 to 30	14,168		62.09	5.32		1.54	17	425	16	458	{ 155 to 160 75 to 80
6	Lynn, Mass.	W. I., C. L. & C. I.	2 to 20	2,659		108.8		146.		3	170	5	936	50 to 65
7	Middleboro, Mass.	C. I.	4 to 12	8,010.8		$15\frac{3}{8}$				6	108	8	148	45 to 60
8	New Bedford, Mass	W. I. C. L. & C. I.	4 to 36	51,259	8,358	84.4116	9.80	14.	6,420 ft	46	670	65	928	26 to 44
9	N. London, Conn.	W. I., C. L. & C. I.	4 to 20	8,623		44.7	18.46	1.	2.04	9	207	19	246	45 to 50
10	Newton, Mass.	C. I.	4 to 20	29,874		$125\frac{7}{10}$	16.06	13.	2.9	35	840	41	684	84
11	Oberlin, Ohio.	C. I.	4 to 12	1,730		8.1			.33	2	74	3	48	27 to 32
12	Plymouth, Mass.	W. I. & C. L.	2 to 20	668		34.	9.38	1.	10.5	3	116	7	319	
13	Reading, Mass.	C. I.	4 to 12	666		20.0412					111	2	195	68 to 78
14	Springfield, Mass.	W. I., C. L. & C. I.	$\frac{3}{4}$ to 36	30,351	8,415	127.8	11.69	.42	39,779 ft	48	841	105	1,545	{ 100 to 120 30 to 35
15	Taunton, Mass.	C. I.	4 to 20	4,349		71.56	29.85	4.	6,415 ft	19	724	9	492	45 to 50
16	Waltham, Mass.	C. I., W. I. & C. L.	2 to 24	1,951		48.1	6.57	1.		10	291	21	623	58
17	Woonsocket, R. I.	C. I.	4 to 20	9,028		42.6	1.76	.23		23	514	19	416	90 to 115
18	Yonkers, N. Y.	C. I.	3 to 30	11,163		60.8	19.00	1.5	.84	18	628	9	373	

1896.—V.—DISTRIBUTION—SERVICE PIPES.

Number.	Name of City or Town.	16 Service Pipe. Kind of Pipe.	17 Service Pipe. Size of Pipe in Inches.	18 Service Pipe. Length Extended Feet.	19 Service Pipe. Length Discontinued Feet.	20 Service Pipe. Length in Use. Miles.	21 Service Taps. No. Added.	22 Service Taps. Total in Use.	23 Av. Length of Service.	24 Av. Cost of Service.	25 Meters. Number added.	26a Meters. Now in Use. Domestic.	26b Meters. Now in Use. Manu-fac'ing.	27 Motors and Elevators. No. added.	28 Motors and Elevators. Total in Use.
1	Attleboro, Mass...									$	54		673		1
2	Bay City, Mich....	Lead, W. I. & Wyckoff.	$\frac{3}{8}$ to 8				7	1,858			61	620			
3	Brockton, Mass....	W. I., L. L., C. L & C. I.	$\frac{3}{4}$ to 6	18,586	433.	24.17	336	4,581		9.06	419	3,382			
4	Burlington, Vt ..	Gal., Lead.	$\frac{1}{2}$ to 6	3,241	211.	16.5	98	3,067	32.34	9.17	291	1,501	51	1	30
5	Fitchburg, Mass...	W. I., C. L. & C. I.	$\frac{3}{4}$ to 8	6,197		44.06	175	4,051	35.	11.20	93	1,695	176	4	70
6	Lynn, Mass......	I., C. L., Ada. Gal., L. L.	$\frac{3}{4}$ to 10	11,116	925.	90.9	264	11,267			355	1,561			
7	Middleboro, Mass.	L., W. I. and C. L.	$\frac{3}{4}$ to 3	1,201		42469f	25	722	50.		17	254	19		5
8	New Bedford, Mass	Lead and Cast Iron.	$\frac{1}{2}$ to 10	15,718	412.	53.06	420	8,447	36.	15.01	112	307	59	2	81
9	New London, Ct. .	G. I., Gal., C. L. and L.	$\frac{1}{2}$ to 4	1,725		10.	78	2,741	19.	13.74	20	187		1	23
10	Newton, Mass. ..	Lead, W. I. and C. I.	$\frac{1}{2}$ to 6	23,097	5,828.	71.	359	6,276	61.	25.50	443	4,958	25	1	17
11	Oberlin, Ohio.....	Gal., Lead.	$\frac{3}{4}$ to 2				28	471	25.	8.00	37	169	5	0	0
12	Plymouth, Mass...	Lead and Cem't Lined.	$\frac{1}{2}$ to 1	423		5 5	43	1,664	17$\frac{2}{3}$	4.50					1
13	Reading, Mass .	G. I., C. L., L. L. & C. I	$\frac{3}{4}$ to 6	4,881		10.27	59	812	82.7	26.58	48	135		0	3
14	Springfield, Mass..	W. I. and C. I.	$\frac{1}{6}$ to 6				398	8,298			92	2,299			172
15	Taunton, Mass....	Cem't L. and W. I.	$\frac{3}{4}$ to 3	1.18m	5,723.42	38.33	119	3,955		19.47	76	1,443	1,297	0	11
16	Waltham, Mass....	C. I. W. I. & C. L.	$\frac{3}{4}$ to 8	4,139	464.	34.1	43	3,085	70.5	24.85	3	75		0	6
17	Woonsocket, R. I.	Lead and Iron.	$\frac{5}{8}$ to 6	1,787		5.5	112	1,872	17.2	12.78	88	1,552	47	3	9
18	Yonkers, N. Y....	Lead and C. I.	$\frac{3}{8}$ to 8				266	3,790			256	3,836	126		9

PROCEEDINGS.

MONTHLY MEETING.

YOUNG'S HOTEL,
Boston, February 9, 1898.

President Kent in the chair. Members and guests were present as follows:

ACTIVE MEMBERS.

Everett L. Abbott, Solon M. Allis, Francis E. Appleton, Charles H. Baldwin, Lewis M. Bancroft, R. S. Bartlett, George E. Batchelder, Joseph E. Beals, James F. Bigelow, Dexter Brackett, John T. Cavanagh, George F. Chace, E. J. Chadbourne, Charles E. Chandler, William F. Codd, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, F. H. Crandall, A. A. Forbes, F. F. Forbes, E. N. French, Frank L. Fuller, J. C. Gilbert, Albert S. Glover, J. A. Gould, E. H. Gowing, Francis C. Green, E. A. W. Hammatt, George W. Harrington, John C. Haskell, F. S. Hollis, Horace G. Holden, Willard Kent, Patrick Kieran, Frank E. Merrill, Leonard Metcalf, Charles F. Murphy, Frank L. Northrop, W. H. Richards, W. W. Robertson, A. H. Salisbury, George A. Stacy, Edwin A. Taylor, Lucian A. Taylor, W. H. Thomas, D. N. Tower, Charles K. Walker, Wm. W. Wade, John C. Whitney, G. E. Winslow, E. T. Wiswall.

ASSOCIATE MEMBERS.

Chadwick Lead Works, by A. H. Brodrick.
Deane Steam Pump Co., by Messrs. Hayes and Bellows.
Ludlow Manufacturing Co., by H. F. Gould.
Hersey Manufacturing Co., by J. Edward Spofford.
Henry F. Jenks, Pawtucket, R. I.
Lead Lined Pipe Co.,
Neptune Meter Co., by H. H. Kinsey.
Perrin, Seamans & Co., by H. L. Bowd.
Rensselaer Manufacturing Co., by F. S. Bates.
Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.
Anthony P. Smith, by W. H. Van Winkle.
Union Water Meter Co., by F. L. Northrop.
R. D. Wood & Co., by Jesse Garrett.
H. R. Worthington, by J. M. Betton.

GUESTS.

Norris J. Alton, Calvin Claflin, J. J. Moore, W. E. Maybury, J. W. McGeary, L. B. Palmer and H. L. Thomas.

The following named gentlemen were elected resident active members:

Benjamin R. Chapman, Civil Engineer, Brockton, Mass.; J. F. Gleason, Foreman of Construction, Quincy, Mass.

The first paper of the afternoon was read by F. H. Crandall, Superintendent, Burlington, Vermont, his subject being "Loss of Water from Pipes." Mr. Brackett, Mr. Whitney, Mr. Richards, Mr. Kieran, Mr. Stacy, Mr. Holden and Mr. Fuller took part in the discussion which followed.

Mr. H. G. Holden, Superintendent, Nashua, N. H., gave a description of the laying of a 24-inch main under the Nashua river. Experiences in similar work were told by Messrs. Crandall, Gowing, Brackett and Gilbert.

Mr. Solon M. Allis, of Malden, Mass., read a paper entitled, "Experiences in the Arid Southwest."

The meeting then adjourned.

QUARTERLY MEETING.

Young's Hotel,
Boston, March 9, 1898.

The following members and guests were present:

ACTIVE MEMBERS.

Francis E. Appleton, George E. Batchelder, Joseph E. Beals, George Bowers, Dexter Brackett, John T. Cavanagh, George F. Chace, E. J. Chadbourne, G. L. Chapin, John C. Chase, Harry W. Clark, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, George K. Crandall, Lucus Cushing, O. A. Doane, John W. Ellis, B. R. Felton, Charles R. Felton, E. N. French, Alphonse Fteley, Frank L. Fuller, J. C. Gilbert, J. F. Gleason, T. C. Gleason, Albert S. Glover, Frederick W. Gow, James H. Harlow, John C. Haskell, T. G. Hazard, Jr., F. S. Hollis, H. N. Hyde, Willard Kent, Frank C. Kimball, James W. Locke, Frank E. Merrill, Leonard Metcalf, Edward C. Nichols, Frank L. Northrop, Edward Phillips, J. B. Putnam, Walter H. Richards, W. W. Robertson, William T. Sedgwick, John E. Smith, George A. Stacy, J. D. Hardy, J. A. St. Louis, Charles H. Swan, Wm. H. Thomas, W. H. Vaughan, Charles K. Walker, William W. Wade, J. Alfred Welch, John C. Whitney, George E. Winslow, E. T. Wiswall, M. N. Baker.

ASSOCIATE MEMBERS.

Coffin Valve Co., by Mr. Weston.
Deane Steam Pump Co., by F. H. Hayes and L. E. Bellows, General Manager.
Drummond, M. J., New York City, N. Y., by W. G. Briggs.
George E. Gilchrist, by H. M. Libbey.
Mellin S. Harlow, Boston, Mass.
Kennedy Valve Co.
Hersey Manufacturing Co., by Albert S. Glover.
The Hydraulic Construction Co., by M. R. Ryder.
Jenks, Henry F., Pawtucket, R. I.
The McNeal Pipe and Foundry Co., by I. S. Haines, Treasurer.
Lead Lined Pipe Co., by T. E. Dwyer.
National Meter Co., by J. Edward Spofford.
Neptune Meter Co., by H. H. Kinsey.
Perrin, Seamans & Co., by H. L. Bond.
Rensselaer Manufacturing Co., by F. S. Bates.
Builders' Iron Foundry, by T. C. Clifford.
Anthony P. Smith, by W. H. Van Winkle.
Sumner & Goodwin Co., by F. D. Sumner.
Union Water Meter Co., by J. P. K. Otis.
R. D. Wood & Co., by Mr. Newhall.
H. R. Worthington, by J. M. Betton.

GUESTS.

C. M. Ames, C. F. Chase, F. B. Endicott, C. E. Fowler and G. L. Turner.

The following named gentlemen were elected active resident members:

George E. Manning, C. E., New London, Conn.
William Walter Ewell, Supt. Water Works, Quincy.
J. D. Hardy, Supt. Holyoke Water Works.
James L. Tighe, Engineer, Holyoke Water Works.
Charles D. Colson, Water Commissioner, Holyoke.
Thomas F. Greaney, Water Commissioner, Holyoke.
John J. Sullivan, Water Commissioner, Holyoke.

Charles E. Fowler, Superintendent and Engineer of the Poughkeepsie Water Works, read a paper entitled "Operation of a Slow Sand Filter." The subject was discussed by Mr. Hazen, Mr. Clark, Mr. Haskell and Prof. Sedgwick.

On motion of the Secretary the thanks of the Association were extended to Mr. Fowler for his paper.

Adjourned.

OBITUARY.

WILLIAM M. HAWES.—Died February 16th, 1898, aged 65 years. Joined this Association June 16th, 1886.

Mr. Hawes was for many years a member of the Board of Water Commissioners of the city of Fall River, Mass., and as such took an active interest in the welfare of this Association. He was a constant attendant at its meetings until stricken with the disease which finally resulted in his death. His genial good fellowship and kindly disposition won the friendship of all the members of the Association by whom his death is sincerely mourned.

New England Water Works Association Membership Roll.

SEPTEMBER 1, 1897.

NOTE. — The Secretary requests to be advised of existing errors or change of address from that which appears in the following list.

ACTIVE MEMBERS — RESIDENT AND NON-RESIDENT.

Abbott, Everett L.
Box 2281, Boston, Mass.

Adams, John D.
Superintendent, Provincetown, Mass.

Allen, Charles A.
Civil Engineer, 44 Front street, Rooms 109 and 110, Worcester, Mass.

Allen, Charles F.
Treasurer, Hyde Park, Mass.

Allis, Solon M.
Civil Engineer, 76 Bell Rock street, Malden, Mass.

Amerman, Lemuel.
Manager Water Works, Coal Exchange, Scranton, Pa.

Andrews, Frank A.
Assistant Superintendent, Nashua, N. H.

Armstrong, S. G.
Box 2139, Johannesburg, South Africa.

Ashwell, Wm. H.
Civil Engineer, 76 Home Bank Building, Detroit, Mich.

Babbidge, P. F.
Superintendent, Keene, N. H.

Babcock, Stephen E.
Chief Engineer, Little Falls, N. Y.

Bacot, R. C., Jr.
Superintendent Meter Department, P. O. Box 461, Port Chester, N. Y.

Badger, Frank S.
Engineer's office Locks and Canals, Lowell, Mass.

Bagnell, Richard W.
Superintendent, Plymouth, Mass.

Bailey, E. W.
City Engineer, Somerville, Mass.

Bailey, Frank S.
Assistant City Engineer, Brockton, Mass.

Bailey, George I.
Superintendent, 61 State street, Albany, N. Y.

Baldwin, Charles H.
Box 2410, or 159 Franklin street, Boston, Mass.

Baldwin, Richard.
Proprietor Water Works, Terryville, Conn.

Bancroft, Arthur G.
Civil Engineer, Box 506, Reading, Mass.

Bancroft, Lewis M.
Superintendent, Reading, Mass.

Barbour, Frank A.
Civil Engineer, P. O. Box 1235, Brockton, Mass.

Barns, Everett.
Superintendent, Westerly, R. I.

Barrett, Albert P.
Woburn, Mass.

Barrus, George H.
Consulting Steam Engineer, 95 Milk street, Boston, Mass.

Bartlett, Charles H.
Civil Engineer, 852 Elm street, Manchester, N. H.

Bartlett, R. S.
Superintendent, Norwich, Conn.

Bassett, Carroll, Ph.
Treasurer Water Co., Summit, N. J.

Batchelder, George E.
Registrar, Worcester, Mass.

Batcheller, Francis.
Commissioner, North Brookfield, Mass.

Bates, Oren B.
Superintendent, Clinton, Mass.

Bates, Theodore C.
29 Harvard street, Worcester, Mass.

Battles, James M.
120 Marginal, cor. Cottage street, East Boston, Mass.

Beals, Joseph E.
Superintendent, Middleboro, Mass.

Beasom, C. B.
Civil Engineer, 248 Tremont street, Newton, Mass.

Benzenberg, G. H.
City Engineer, Milwaukee, Wis.

Berkey, John A.
Pres. Electric and Water Co., Little Falls, Minn.

Bettes, C. B.
Engineer Queens Co. Water Co., Far Rockaway, N. Y.

Bickford, Nathan B.
61 Minot street, Neponset, Mass.

Bigelow, James F.
City Engineer, Marlboro, Mass.

Billings, William R.
15 Harrison street, Taunton, Mass.

Birkinbine, Harry.
Civil Engineer, Wayne, Delaware County, Penn.

Bisbee, Forrest E.
Superintendent, Auburn, Me.

Bishop, George H.
Civil Engineer, Middletown, Conn.

Bishop, Watson L.
Superintendent, Darthmouth, N. S.

Bliss, Gerald M.
Civil Engineer, 19 Cottage street, Providence, R. I.

Blossom, William L.
Civil Engineer, 355 Washington street, Brookline, Mass.

Boggs, Edward M.
Chief Engineer California Power Co., Redlands, Cal.

Bowers, George.
City Engineer, Lowell, Mass.

Brackett, Dexter.
Engineer Distribution Dept. Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Bradley, R. H.
Receiver, Marshall and Burdick, Contracting Engineers, Watertown, South Dakota.

Brinsmade, Daniel S.
Engineer and Agent Ousatonic Water Co., Birmingham, Conn.

Broatch, J. C.
Superintendent, Middletown, Conn.

Brooks, E. C.
Superintendent, Cambridge, Mass.

Brown, Arthur W. F.
Registrar, Fitchburg, Mass.

Brown, Edward H.
Superintendent and Treasurer Nevada County, N. G. R. R., Grass Valley, Cal.

Brown, J. Henry.
3 Tremont street, Charlestown, Boston, Mass.

Brown, Walter I.
Registrar, Bangor, Me.

Brownell, Ernest H.
Civil Engineer, Army Building, New York City, N. Y.

Bryant, C. B.
City Engineer, Martinville, Va.

Buckman, Geo. A. P.
Superintendent, Norwood, Mass.

Burke, James E.
Superintendent Princeton Water Co., Princeton, N. J.

Burleigh, John M.
Superintendent, South Berwick, Me.

Burley, Harry B.
31 Milk street, Room 55, Boston, Mass.

Burnham, Albert S.
Superintendent, Revere, Mass.

Burnie, James.
Superintendent, Biddeford, Me.

Burr, William H.
Professor of Civil Engineering, Columbia College, and Consulting Engineer, New York City.

Bush, Edward W.
17 De Forest street, Binghampton, N. Y.

Butler, J. Allen.
Superintendent, Portland, Conn.

Cairns, R. A.
City Engineer, Waterbury, Conn.

Card, Huber D.
City Engineer, Willimantic, Conn.

Carroll, Fred. B.
8 Dexter street, Woonsocket, R. I.

Cavanagh, John T.
Water Commissioner, Quincy, Mass.

Chace, George F.
Superintendent, Taunton, Mass.

Chadbourne, E. J.
Superintendent, Wakefield, Mass.

Chandler, Charles E.
City Engineer, 161 Main street, Norwich, Conn.

Chandler, Charles F.
Professor of Chemistry, School of Mines, Columbia College, New York City.

Chandler, Henry.
Water Commissioner, Manchester, N. H.

Chapin, G. L.
Water Commissioner, Lincoln, Mass.

Chase, John C.
Chief Engineer Water Works, Wilmington, N, C. Address, Derry, N. H.

Childs, Wm. H.
Treasurer Manchester Water Co., 880 Carroll street, Brooklyn, N. Y.

Clapton, Wm.
Superintendent, Newtown, N. Y.

Clark, A. D.
Secy. Spring Water Co., Kane, Pa.

Clark, D. W.
President Water Co., Portland, Me.

Clark, Frederick W.
Clerk Chestnut Hill Reservoir, Boston, W. W., Brighton, Mass.

Clark, Harry W.
State Experiment Station, Lawrence. Mass.

Clarke, E. W.
95 Milk street, Room 54, Boston, Mass.

Cleaveland, W. F.
Sewer Commissioner, Brockton, Mass.

Cochran, Robert L.
Superintendent, Nahant, Mass.

Codd, William F.
Superintendent, Nantucket, Mass.

Coffin, Freeman C.
Civil and Hydraulic Engineer, 53 State street, Boston, Mass.

Coggeshall, R. C. P.
Superintendent, New Bedford, Mass.

Colby, H. L.
Civil Engineer, Salem, Mass.

Cole, F. M.
Inspector, Brockton, Mass.

Collins, Lewis P.
Water Commissioner, Lawrence, Mass.

Conant, H. W.
Superintendent, Gardner, Mass.

Conant, Whitney.
Secretary, Water Co., Long Branch, N. J.

Congdon, John L.
East Greenwich, R. I.

Connell, Michael A.
Superintendent, St. Hyacinthe, P. Q.

Cook, Byron I.
Superintendent, Woonsocket, R. I.

Cook, Henry A.
Superintendent, Salem, Mass.

Cram, Arthur N.
Water Commissioner, Walpole, Mass.

Crandall, F. H.
Superintendent and Treasurer, Burlington, Vt.

Crandall, George K.
Civil Engineer, New London, Conn.

Crawford, J. W.
Clerk Water Board, Lowell, Mass.

Crilly, P. F.
Superintendent, Woburn, Mass.

Croes, J. J. R.
Civil Engineer, 68 Broad street, Morris Building, New York City.

Crowell, George E.
President Water Works, Brattleboro, Vt.

Cushing, Lucas.
Box 108, Mansfield, Mass.

Daboll, L. E.
Civil Engineer, New London, Conn.

Davis, F. A. W.
Vice-President and Treasurer Water Co., Indianapolis, Ind.

Davis, J. M.
Rutland, Vt.

Davis, William E.
Superintendent, Sherburne, N. Y.

Davison, George S.
Civil Engineer, Pittsburg, Penn.

Dawson, Alex. S.
Eng. Department Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Dean, Francis W.
Mechanical Engineer, Exchange Building, 53 State street, Boston, Mass.

Dean, Seth.
Civil Engineer, Glenwood, Iowa.

Dean, Wm. H.
Water Analyst, Wilkesbarre, Pa.

Decker, J. H.
Room 37, Municipal Building, Brooklyn, N. Y.

Denman, A. N.
Secretary and Manager, Des Moines, Iowa.

Dennett, Nathaniel.
Superintendent, Somerville, Mass.

Denton, J. E.
Professor of Experimental Mechanics, Stevens Institute, Hoboken, N. J.

Diven, J. M.
Superintendent Water Co., Elmira, N. Y.

Doane, A. O.
Eng. Department Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Dolan, Edward.
Superintendent, Troy, N. Y.

Doran, Hugh F.
Superintendent, Port Huron, Mich.

Dotten, William T.
Superintendent, Winchester, Mass.

Drake, Albert B.
Civil Engineer, 164 William street, New Bedford, Mass.

Drake, B. Frank.
Water Commissioner, Lakeport, N. H.

Drake, Charles E.
Civil Engineer, New Bedford, Mass.

Drown, Thomas M.
President Lehigh University, South Bethlehem, Pa.

Dunbar, E. L.
Superintendent, Bay City, Mich.

Dyer, Eben R.
Superintendent Distribution, Portland, Me.

Eardley, B. A.
Superintendent Pacific Improvement Co. Water Works, Pacific Grove, Monterey Co., Cal.

Eastman, Henry E.
Superintendent, Westport, N. Y.

Eddy, Chas. E.
President Water Co., Plattsmouth, Neb. Address, 35 Congress street, Boston, Mass.

Eddy, Harrison P.
Supt. Sewer Department, City Hall, Worcester, Mass.

Eglee, Chas. H.
Hydraulic Engineer, 53 State street, Boston, Mass.

Ellis George A.
Civil Engineer, 158 Sherman street, Springfield, Mass.

Ellis, John W,
Civil Engineer, Woonsocket, R. I.

Ellison, W. P.
President Water Board, Newton, Mass.

Ellsworth, Emory A.
Civil Engineer, Holyoke, Mass.

Ervin, John.
Secretary and Treasurer Middleton Water Supply Co., Bridgetown, N. S.

Evans, George E.
Civil Engineer, 95 Milk street, Boston, Mass.

Fairbanks, J. H.
Chairman Water Commissioners, Winchendon, Mass.

Fales, Frank L.
Eng. Dept. Metro. Water Board, 3 Mt. Vernon street, Boston, Mass.

Fanning, John T.
Consulting Engineer, Kasota Block, Minneapolis, Minn.

Farnham, Elmer E.
Superintendent, Box 109, Sharon, Mass.

Farnum, Loring N.
Hydraulic Engineer, 53 State street, Boston, Mass.

Felton, B. R.
Civil Engineer, Tremont Building, Boston, Mass.

Felton, Charles R.
Asst. Engineer Sewerage Commissioners' Office, Brockton, Mass.

Fifield, John W. D.
Water Commissioner, North Brookfield, Mass.

Fish, J. B.
Superintendent, Scranton, Pa.

Fiske, Wilbur D.
48 Arch street, Boston, Mass.

FitzGerald, Desmond.
Superintendent Western Division and Resident Engineer, Additional Supply Boston Water Works, and Engineer Sudbury Dept. Metropolitan Water Board. Address, Brookline, Mass.

Flinn, Richard J.
Pumping Engineer, Brookline, Mass. Address, W. Roxbury, Mass.

Fobes, A. A.
Engineer Board of Public Works, Pittsfield, Mass.

Forbes, F. F.
Superintendent, Brookline, Mass.

Forbes, Murray.
Manager Westmorland Water Co., Greensburgh, Penn.

Forbes, Z. R.
Water Registrar, Brookline, Mass.

Foss, William E.
Engineers' Dept. Metro. Water Board, 3 Mt. Vernon street, Boston, Mass.

Foster, Joel.

Superintendent, Montpelier, Vt.

Foye, Andrew E.

Civil Engineer, 11 Broadway, New York city.

Freeman, John R.

President Factory Insurance Cos., Providence, R. I.

French, D. W.

Superintendent Hackensack Water Co., No. 1 Newark street, Hoboken, N. J.

Fteley, Alphonse.

Chief Engineer Aqueduct Commissioners, 213 Stewart Building, New York city.

Fuller, Frank L.

Civil Engineer, 12 Pearl street, Room 35, Boston, Mass.

Fuller, Geo. W.

Chief Chemist and Bacterologist Water Co., Louisville, Ky.

Gamwell, J. H.

Treasurer Water Company, Palmer, Mass.

Gardner, L. H.

Superintendent Water Works Company, New Orleans, La.

Geer, Harvey M.

Civil Engineer, Ballston Spa, N. Y.

Gerhard, William Paul.

Civil Engineer, Consulting Engineer for Sanitary Works, 36 Union Square, East, New York City.

Gerrish, William B.

Superintendent and Engineer, Oberlin, Ohio.

Gerry, L. L.

Civil Engineer, Room 1, Chase's Block, Stoneham, Mass.

Gilbert, Julius C.

Superintendent, Whitman, Mass.

Gilderson, D. H.

Superintendent, Bradford, Mass.

Gleason, Fred B.

Inspector, Marlboro, Mass.

Gleason, T. C.
Superintendent, Ware, Mass.

Glover, Albert S.
Tremont Temple Bldg, Boston, Mass.

Goodier, Andrew B.
Treasurer and Superintendent, Southbridge, Mass.

Goldthwait, W. J.
Marblehead, Mass.

Goodnough, X. H.
Engineer, State Board of Health, Room 140, State House, Boston, Mass.

Goodwin, John A.
Box 439, Madison, Me.

Gould, Amos A.
Water Commissioner, Leicester, Mass.

Gould, J. A.
Engineer in charge distribution Boston, Brookline & Bay State Gas Light Cos., 24 West street, Boston, Mass.

Gow, Frederick W.
Superintendent, Medford Mass.

Gowing, E. H.
95 Milk street, Boston, Mass.

Graham, James W.
Superintendent Meter Dept., Portland, Maine.

Greene, S. C.
Chairman Water Board, St. Albans, Vt.

Gregg, Herman.
Civil Engineer, 23 Willow street, Waltham, Mass.

Greetham, H. W.
Local Manager, Water and Sewerage Co., Orlando, Fla.

Griffith, William E.
Secretary Water Commissioners, Cumberland, Md.

Groce, William R.
Superintendent, Rockland, Mass.

Gubelman, F. J.
Civil Engineer, 792 Montgomery street, Jersey City, N. J.

Hale, Richard A.

Principal Assistant Engineer, Essex Company, Lawrence, Mass.

Hall, Frank E.

Box 124, Quincy, Mass.

Hammett, E. A. W.

Civil Engineer, 29 Pemberton square, Boston, Mass.

Hammond, J. C. Jr.

Secretary and Treasurer, Rockville, Conn.

Hancock, Joseph C.

Superintendent, Springfield, Mass.

Haring, James S.

Civil Engineer, Lock Box 74, Nyack, Rockland, Co., N. Y.

Harlow, James H.

President Penn. Water Co., Wilkinsburg, Pa., address Station D, Pittsburg, Pa.

Harrington, Geo. W.

Wakefield, Mass.

Harris, D. A.

Superintendent, New Britain, Conn.

Hart, Edward W.

General Manager Water Works, Council Bluffs, Iowa.

Hartwell, David A.

City Engineer, Fitchburg, Mass.

Haskell, John C.

Superintendent, Lynn, Mass.

Hastings, L. M.

City Engineer, Cambridge, Mass.

Hastings, V. C.

Superintendent, Concord, N. H.

Hatch, Arthur Elliot.

Mechanical Engineer, Bay State Dredging Co., 59 High street, Boston, Mass.

Hatch, S. S.

Water Commissioner, So. Norwalk, Conn.

Hathaway, A. R.

Registrar, Springfield, Mass.

Hathaway, James H.
Registrar, New Bedford, Mass.

Hawes, Geo. Mason.
Civil Engineer, 81 Bedford street, Fall River, Mass.

Hawes, Louis E.
Civil Engineer, Tremont Building, Boston, Mass.

Hawes, William B.
Water Commissioner, Fall River, Mass.

Hawes, William M.
Fall River, Mass.

Hawks, William E.
President and Treasurer, Bennington, Vt.

Hayes, Ansel G.
Assistant Superintendent, Box 323, Middleboro, Mass.

Hazard, T. G., Jr.
Civil Engineer, Narragansett Pier, R. I.

Hazen, Allen.
Civil Engineer, 220 Broadway, New York, N. Y.

Heald, Simpson C.
Civil Engineer, 48 Congress street, Boston, Mass.

Heermans, Harry C.
Superintendent, Corning, N. Y.

Henderson, Wilson.
Superintendent, Peterborough, Ontario, Canada.

Hering, Rudolph.
Civil and Sanitary Engineer, 100 William street, New York City.

Herschel, Clemens.
Hydraulic Engineer, 2 Wall street, Room 66, New York City.

Hicks, R. S.
75 Warren street, New York, N. Y.

Higgins, James H.
Supt. Meter Department, City Hall, Providence, R. I.

Hill, Hibbert.
Biologist Rockville Centre Laboratory of Brooklyn Dept. of Health. Address, Rockville Centre, Long Island, N. Y.

Hill, William R.
Chief Engineer, Syracuse, N. Y.

Hodgdon, Frank W.
Water Commissioner, Arlington, Mass.

Hodgdon, John S.
Wellington, Mass.

Holden, Andrew.
Water Commissioner, Fall River, Mass.

Holden, Horace G.
Superintendent, Nashua, N. H.

Holman, M. L.
Water Commissioner, 3744 Finney avenue, St. Louis, Mo.

Hopkins, Chas. C.
Stanwix Engineering Co., Rome, N. Y.

Hunking, Arthur W.
Care Mass. Mills, Rome, Ga.

Hunter, Henry G.
Civil Engineer, John Hancock Building, Boston, Mass.

Huntington, James A.
Registrar, Haverhill, Mass.

Hyde, Horatio N.
Superintendent, Newtonville, Mass.

Inman, A. W.
Superintendent Water Supply Co., Massillon, Ohio.

Jackson, Daniel D.
Water Analyst Boston Water Works, Newtonville, Mass.

Jackson, William.
City Engineer, City Hall, Boston, Mass.

Johnson, William S.
Assistant Engineer State Board of Health, Room 140, State House, Boston, Mass.

Jones, A. J.
New Brunswick, N. J.

Jones, James A.
Registrar, Stoneham, Mass.

Jones, R. A.
Civil Engineer, Spokane, Washington.

Jordan, John N.
Superintendent, Malden, Mass.

Junkins, Geo. S.
Water Commissioner, Lawrence, Mass.

Keating, E. H.
City Engineer, Toronto, Ontario, Canada.

Kempton, David B.
Water Commissioner, New Bedford, Mass.

Kent, E. W.
Civil Engineer, Woonsocket, R. I.

Kent, Willard.
Manager Water Co., Narragansett Pier, R. I.

Kieran, Patrick.
Superintendent, Fall River, Mass.

Kimball, Frank C.
Civil Engineer, 89 State street, Boston, Mass.

Kimball, George A.
Member Metropolitan Sewerage Board, Room 1102, Exchange Building, 53 State street. Boston, Mass.

King, E. W.
Secretary and Treasurer, Great Falls, Mont.

Kingman, Horace.
Superintendent, Brockton, Mass.

Kinnicutt, Leonard P.
77 Elm street, Worcester, Mass.

Kinsey, Warren R.
Civil Engineer, 108 Fulton street, New York City.

Knapp, Louis H.
Assistant Superintendent and Engineer, Dept. Public Works Bureau of Water, 280 Linwood avenue, Buffalo, N. Y.

Knight, Chas. Wm.
Stanwix Engineering Co., Rome, N. Y.

Knowles, Morris.
Resident Engineer Filtration Commission Water Supply Dept., Pittsburg, Pa.

Koch, Harry G.
Superintendent Castle Creek Water Co., Aspen, Colorado.

Kuehn, Jacob L.

Superintendent, York, Penn.

Laforest, J. O. Alfred.

Superintendent, Montreal, Quebec.

Laing, W. H.

Superintendent Water Co., Racine, Wisconsin.

Landon, H. C.

Civil Engineer, 728 East Capitol avenue, Springfield, Ill.

Lansing, Edward T. E.

Civil Engineer, Little Falls, N. Y.

Lawton, Perry.

Civil Engineer, 39 Washington street, Quincy, Mass.

Lea, R. S.

Civil Engineer, 53 State street, Boston, Mass.

Learned, Wilbur F.

Civil Engineer, Watertown, Mass.

Leckie, R. G. Edwards.

Constructing Engineer, Torbrook, N. S.

Locke, James W.

Foreman, Brockton, Mass.

Lockwood, Joseph A.

Superintendent, Yonkers, N. Y.

Lord, Harry A.

Superintendent, Ogdensburg, N. Y.

Loretz, Arthur J. L.

Mechanical Engineer, 122 Liberty street, New York City.

Lovell, Thomas C.

Superintendent. Office 104 River street, Fitchburg, Mass.

Luce, Francis H.

Superintendent, Woodshaven, N. Y.

Lunt, Cyrus M.

Superintendent, Lewiston, Me.

Lusk, James L.

Capt. Corps. of Engineers, U. S. A., in charge of Water Supply U. S. Military Academy, West Point, N. Y.

Luther, William J.

Superintendent and Registrar, Attleboro, Mass.

Mann, Charles W.
Water Commissioner, Methuen, Mass.

Mann, Thomas W.
Civil Engineer, Holyoke, Mass.

Marble, Arthur D.
City Engineer, Lawrence, Mass.

Marion, J. A.
Civil Engineer, Temple Building, Montreal, P. Q.

Martin, A. E.
Superintendent, South Framingham, Mass.

Martin, Cyrus B.
Treasurer Water Company, Norwich, N. Y.

Martine, Alfred H.
Consulting Engineer, Middlesborough, W. W., Kentucky.

Marvell, Edward I.
Civil Engineer, 81 Bedford street, Fall River, Mass.

Mason, William P.
Prof. of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.

Mattice, Asa M.
Mechanical Engineer, with E. D. Leavitt, 2 Central Square, Cambridgeport, Mass.

Maxcy, Josiah S.
Treasurer, Gardiner, Me.

McClintock, W. E.
Member Mass., Highway Commission, 15 Court Square, Boston, Mass.

McClure, Frederick A.
City Engineer, Worcester, Mass.

McConnell, B. D.
154 Greene avenue, Cote St. Antoine, Quebec.

McCarthy, Daniel B.
Superintendent, Waterford, N. Y.

McDonald, M. L.
Superintendent and Secretary, Santa Rosa, California.

McIntosh, H. M.
City Engineer, Burlington, Vt.

McKenzie, Theodore H.
Manager, Water Works, Southington, Conn.

McKenzie, Thomas.
Civil Engineer, 174 Weybosset street, Providence, R. I.

MacMurray, John C.
President Cherryvale Water Co., Cherryvale, Kan.

McNally, William.
64 Chestnut street, Marlboro, Mass.

Merrill, Frank E.
Clerk Water Board, Somerville, Mass.

Merritt, D. S.
Engineer and Superintendent Water Works, Tarrytown, N. Y.

Metcalfe, Henry.
President Water Board, Cold Spring, N. Y.

Metcalf, Leonard.
Civil Engineer, 89 State street, Boston, Mass.

Miller, John F.
Secretary and Superintendent, E. Pittsburg, Pa.

Miller, T. D.
Secretary, Norwich, N. Y.

Mills, Frank H.
Civil Engineer, Woonsocket, R. I.

Mirick, George L.
Civil Engineer, 49 Glen avenue, Malden, Mass.

Molis, William.
Superintendent, Muscatine, Iowa.

Morse, James W.
Superintendent, Natick, Mass.

Murphy, Charles F.
Inspector, Marlboro, Mass.

Myers, J. H., Jr.
Eng Dept. Water Supply 41 Municipal Bldg., Brooklyn, N. Y.

Nash, H. A., Jr.
Civil Engineer, John Hancock Building, Boston, Mass.

Naylor, Thomas.
Superintendent, Maynard, Mass.

Nettleton, Charles H.
Treasurer and Superintendent, Birmingham, Conn.

Newhall, John B.
Engineer and Superintendent, Crystal Water Co., Stapleton, Staten Island.

Nichols, Edward C.
Water Commissioner, Lock Box 56, Reading, Mass.

Nichols, Thomas P.
Member Water Board, 11 Prospect street, Lynn, Mass.

Northrop, Frank L.
Milford, Mass.

Nuebling, Emil L.
Engineer and Superintendent, Reading, Pa.

Nye, George H.
Civil Engineer, New Bedford, Mass.

Nye, Joseph K.
President Water Co., Fairhaven, Mass.

Paine, C. W.
Civil Engineer, Messina, San Bernardino Co., Cal.

Paret, Milnor P.
Resident Engineer K. C. S. and G. Ry., Lake Charles, La.

Parker, Horatio N.
Assistant Biologist Boston Water Works, 54 Concord avenue, Cambridge, Mass.

Parks, Charles F.
Civil Engineer, 89 State street, Boston, Mass.

Parsons,, Frank N.
Clerk Water Board, Franklin, N. H.

Patch, Walter Woodbury.
Civil Engineer, Box 82, Marlboro, Mass.

Pease, A. G.
Water Commissioner, Spencer, Mass.

Perkins, John H.
Superintendent, Watertown, Mass.

Perry, Fred G.
Assistant Commissioner Public Works, Pawtucket, R. I.

Phipps, Edward H.
Superintendent West Haven Water Co., New Haven, Conn.

Pickles, Fred. H.
Superintendent and Engineer, Winona, Minn.

Peirce, Charles E.
Superintendent, East Providence, R. I.

Pitman, Winthrop M.
Treasurer No. Conway Water and Imp. Co. Address No. 493 Centre street, Jamaica Plain, Mass.

Pitney, Frederic V.
Engineer Morristown Aqueduct Co., Morristown, N. J.

Pittman, William.
General Manager Water Works, Box 305, Jerseyville, Ill.

Pollard, William D.
General Manager Water Co., Pottsville, Penn.

Porter, Dwight.
Professor Hydraulic Engineering, Massachusetts Institute of Technology, Boston, Mass.

Potter, Alexander.
Civil and Sanitary Engineer, 137 Broadway, New York City.

Poussin, Ludovic de la Vallee.
Constructing Engineer, P. O. Box 1144, Montreal, P. Q.

Pratt, Charles W.
Superintendent, Utica, N. Y.

Rawson, Waldo E.
Superintendent, Uxbridge, Mass.

Reed, D. A.
City Engineer, Duluth, Minn.

Reynolds, E. H.
Brockton, Mass.

Rice, George S.
Civil Engineer, 95 Milk street, Boston, Mass.

Rice, James L.
Superintendent, Claremont, N. H.

Rice, L. Fredk.
Architect and Civil Engineer, 125 Milk street, Boston, Mass.

Richards, H. D. C.
Manager Water Works, 123 Liberty street, New York City.

Richards, Walter H.
Superintendent, New London, Conn.

Richardson, Charles W.
Commissioner, 8 High street, Everett, Mass.

Richardson, T. F.
Dept. Engineer Metropolitan Water Board, Clinton, Mass.

Ridpath, J. W.
Secretary and Manager, Jenkintown, Penn.

Ries, George J.
Superintendent, Weymouth Centre, Mass.

Ringrose, J. W.
New Britain, Conn.

Roberts, Vaughan M.
Civil Engineer, 700 and 701 Lewis Block, Pittsburg, Penn.

Robertson, George H.
Superintendent of Lake George Water Co., Yarmouth, N.S.

Robertson, W. W.
Water Registrar, Fall River, Mass.

Robinson, A.
Superintendent, Benicia, California.

Roden, Thomas.
Superintendent, Arlington, Mass.

Rogers, Henry W.
Superintendent, Haverhill, Mass.

Rogers, Thomas H.
Pumping Engineer, Nashua, N. H.

Rotch, William.
Civil Engineer, Room 742, Exchange Building, 53 State street, Boston, Mass.

Roullier, G. A.
Superintendent, Flushing, N. Y.

Royce, Harley E.
Assistant Engineer, Brookline, Mass.

Russell, Daniel.

Everett, Mass.

Ryle, William.

Superintendent, Patterson, N. J.

Salisbury, A. H.

Superintendent, Lawrence, Mass.

Sanborn, Willard T.

Superintendent, 87 Portland street, Dover, N. H.

Sanders, George O.

President Water Works Co., Hudson, N. H.

Sando, W. J.

Mechanical Engineer, 25 Mansfield street, Allston, Mass.

Saville, Caleb M.

Eng. Dept. Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Sawyer, Frederick W.

Water Registrar, Milford, N. H.

Sealy, W. F. P.

Superintendent, Potsdam, N. Y.

Sedgwick, William T.

Professor of Biology, Mass. Inst. of Technology, Boston, Mass.

Shedd, Edward W.

Civil Engineer, 10 Hermitage Lane, Worcester, Mass.

Shedd, J. Herbert.

Consulting Engineer, City of Providence, City Hall, Providence, R. I.

Shepard, F. J.

Treasurer, Derry, N. H.

Sherman, William B.

Mechanical Engineer, Box 379, Providence, R. I.

Sherrerd, Morris R.

Engineer Water Department, Newark, N. J.

Shippee, John D.

Superintendent and Secretary, Holliston, Mass.

Shirreffs, Reuben.

Eng. Dept. Metro. Water Board, 3 Mt. Vernon street, Boston, Mass.

Sinclair, Melville A.
Superintendent, Bangor, Me.

Smith, Herbert E.
Prof. Chemistry, Yale Medical School. Address, 430 George street, New Haven, Conn.

Smith, H. O.
Water Commissioner, Leicester, Mass.

Smith, John E.
Superintendent, Andover, Mass.

Smith, J. Waldo.
Civil Engineer, Montclair, N. J.

Smith, Sidney.
Civil Engineer, Rutland, Vt.

Smith, Solon F.
Superintendent and Treasurer Water Co., Grafton, Mass.

Snow, Edwin W.
Civil Engineer, 14 Carleton street, Somerville, Mass.

Sparks, H. T.
Superintendent Water Department, Public Works Co., Bangor, Me. Address Box 208, Brewer, Me.

Springfield, John F.
Civil Engineer, 64 Summer street, Rochester, N. H.

Stacy, George A.
Superintendent, Marlborough, Mass.

Starr, William W.
Civil Engineer, Room 2, City Hall, Bridgeport, Conn.

Stearns, Frederic P.
Chief Engineer, Metro. Water Board, 3 Mt. Vernon street, Boston, Mass.

Stoddard, S. G., Jr.
Engineer Hydraulic Co., 207 Water street, Bridgeport, Conn.

Stone, Charles A.
Electrical Engineer, 4 Post Office square, Boston, Mass.

Sullivan, Eugene S.
Superintendent Mystic Division, Charlestown, Boston, Mass.

Sullivan, John C.
Water Registrar, Holyoke, Mass.

Sutherland, D. A.

Member of Water Board, Lynn, Mass.

Swain, George F.

Professor of Civil Engineering, Mass. Inst. of Technology, Boston, Mass.

Swan, Charles H.

Assistant Engineer Boston Transit Commission, 60 State street, Boston, Mass.

Swan, Joseph W.

Assistant Clerk Water Commis. office, Boston, Mass.

Swett, William P.

Southern Pines, Moore Co., N. C.

Tabb, William B.

Civil Engineer, No. 18 Norton Building, Louisville, Ky.

Taylor, Edwin A.

Constructing Engineer, 73 Tremont street, Boston, Mass.

Taylor, Frederick L.

Engineer, Brookline Water Works, Brookline, Mass.

Taylor, Lucian A.

Civil Engineer and Contractor, 73 Tremont street, Boston, Mass.

Tenney, D. W

Water Commissioner, Methuen, Mass.

Tenney, Joseph G.

Treasurer and Superintendent, Leominster, Mass.

Thomas, Robert J.

Superintendent, Lowell, Mass.

Thomas, William H.

Superintendent, Hingham, Mass.

Thomson, John.

Hydraulic Engineer, 253 Broadway, New York City.

Tingley, R. H.

Civil Engineer, 75 Westminster street, Providence, R. I.

Tinkham, S. Everett.

Assistant Engineer, Engineering Department, City Hall, Boston, Mass.

Tompkins, Charles H.

Civil Engineer, No. 120 Liberty street, New York City.

Tower, D. N.
Superintendent, Cohasset, Mass.

Treman, E. M.
Superintendent and Secretary, Ithaca, N. Y.

Tribus, Louis L.
Civil Engineer, No. 84 Warren street, New York City.

Truesdell, C. H.
Civil Engineer, Killingly, Conn.

Tryon, James E.
Water Supply Engineer, Fire Commission, Detroit, Mich.

Turner, H. N.
Manager Water Co., St. Johnsbury, Vt.

Tuttle, Arthur S.
Civil Engineer, Dept. Water Supply, 82d street, near 11th avenue, Brooklyn, N. Y.

Tubbs, J. Nelson.
Consulting Engineer, 405 Wilder Building, Rochester, N. Y.

Vaughan, W. H.
Superintendent, Wellesley Hills, Mass.

Walker, Charles K.
Superintendent, Manchester, N. H.

Walker, John.
Civil Engineer, Newmarket, N. H.

Walker, Sidney G.
Civil Engineer, 31 Milk street, Room 55, Boston, Mass.

Wallace, E. L.
Superintendent, Franklin Falls, N. H.

Warde, John S.
Superintendent Staten Island Water Co., West New Brighton, Staten Island, N. Y.

Wardsworth, A. R.
Civil Engineer, Farmington, Conn.

Warren, H. A.
Superintendent, St. Albans, Vt.

Watters, Joseph.
Water Commissioner, Fall River, Mass.

Webster, F. P.
Superintendent, Lakeport, N. H.

Welch, J. Alfred.
Superintendent, Methuen, Mass.

Wescott, George P.
Treasurer Portland Water Co., Portland, Me.

Weston, Robert S.
First Assistant Chemist Louisville Water Co., Louisville, Ky.

Wheeler, Elbert.
Treasurer Water Co., Knoxville, Tenn. Address, 37 East Pearl street, Nashua, N. H.

Wheeler, Warren B.
Assistant City Engineer, Fitchburg, Mass.

Wheeler, William.
Civil Engineer, 89 State street, Boston, Mass.

Whipple, George C.
Biologist, Brooklyn Water Works, Brooklyn, N. Y.

Whitcomb, W. H.
President Water Co., Norway, Me.

Whitham, Jay M.
Mechanical Engineer, 131 South Third street, Philadelphia, Pa.

Whitman, Herbert T.
Civil Engineer, 85 Devonshire street, Boston, Mass.

Whitney, John C.
Water Registrar, West Newton, Mass.

Whittemore, W. P.
Superintendent Electric Light and Water Depts., North Attleboro, Mass.

Whittier, Herbert F.
253 Jackson street, Lawrence, Mass.

Wigal, James P.
Superintendent and Engineer, Henderson, Ky.

Wilcox, William C.
Waltham, Mass.

Wilde, George E.
Duxbury, Mass.

Wilder, Frederick W.
Treasurer Aqueduct Co., Woodstock, Vt.

Williams, G. S.
Engineer Water Dept., Detroit, Mich.

Williams, William F.
City Engineer, New Bedford, Mass.

Winship, Horace B.
Civil Engineer, Norwich, Conn.

Winslow, Frederic I.
Assistant Engineer, City Engineer's office, City Hall, Boston, Mass.

Winslow, George E.
Waltham, Mass.

Winslow, S. J.
Superintendent, Pittsfield, N. H.

Wiswall, E. T.
Water Commissioner, West Newton, Mass.

Wood, Henry B.
Executive Engineer Street Department, Room 47, City Hall, Boston, Mass.

Woodruff, Timothy.
Superintendent, Bridgeton, N. J.

Woods, Henry D.
City Engineer, West Newton, Mass.

Worthington, E., Jr.
Civil Engineer, Dedham, Mass.

Wright, George W.
Chief Engineer, Box 426, Norfolk, Va.

Wright, Luther C.
Superintendent, Northampton, Mass.

Yorston, W. G.
Constructing Engineer, Box 478, Truro, N. S.

Zick, W. G.
253 Broadway, New York City.

HONORARY MEMBERS.

Frost, George H.
Engineering News, Tribune Building, New York City.

Gale, James M.

Engineer-in-Chief, Loch Katrine Water Works, Glasgow, Scotland.

Jones, E. R.

561 Shawmut avenue, Boston, Mass.

Meyer, Henry C.

The Engineering Record, 100 William street, New York City.

Shepperd, F. W.

Fire and Water, Box 128, 93 and 97 William street, New York City.

ASSOCIATE MEMBERS.

Allis, The Edward P. Co.

"High Duty Pumping Engines," Milwaukee, Wis.

Ashton Valve Co.

"Water Relief Valves," 271 Franklin street, Boston, Mass

Betton, James M.

Agent H. R. Worthington, 70 Kilby street, Boston, Mass.

Blake, The George F. Mfg. Co.

"Pumping Engines," 95 and 97 Liberty street, New York. City.

Boston Lead Mfg. Co.

162 Congress street, Boston, Mass.

Brandt, Randolph.

"Selden Patent Packing," 38 Cortlandt street, New York City.

Brewster, H. M. (E. Stebbins Mfg. Co.)

"Brass Goods," Brightwood P. O., Springfield, Mass.

Chadwick Lead Works.

176 to 184 High street, Boston, Mass.

Chapman Valve Mfg. Co.

"Valves and Hydrants," Indian Orchard, Mass.

Coffin Valve Co.

"Valves and Hydrants," Neponset, Boston, Mass.

Crosby Steam Gage and Valve Co.

"Gages, Valves, etc.," Robert Pirie, Manager, N. E. Sales Dept., 93 Oliver street, Boston, Mass.

Davidson, M. T.

"Steam Pumps," 43 and 53 Keap street, Brooklyn, N. Y.

Deane Steam Pump Co.

"Steam-pumps and pumping machinery," Holyoke, Mass.

Dibble, F. J.

"Electric Indicators," Peabody, Mass.

Drummond, M. J.

"Cast Iron Pipe," 192 Broadway, Corbin Building, New York City.

Dunne, George C.

Manager Portland Stoneware Co., 42 Oliver street, Boston, Mass.

Eagle Oil and Supply Co.

100 Broad street, Boston, Mass.

Fairbanks Co., The.

"Valves," 77 and 79 Milk street, Boston, Mass.

Frost & Adams Co.

"Architects' Supplies," 37 Cornhill, Boston, Mass.

Garlock Packing Co.

"Packing," 12 Pearl street, Boston, Mass.

Gallison, William H. Co.

"Engineers Supplies, Pipe, etc.," 36 Oliver street, Boston, Mass.

General Manufacturing Co.

"Pumping Engines and Hydraulic Specialties," 417 Franklin avenue, Brooklyn, N. Y.

Gilchrist, George E.

"Pipes and Fittings," 106 High, corner Congress street, Boston, Mass.

Giles, Jason.

Chapman Valve Mfg. Co., "Valves and Hydrants," Indian Orchard, Mass.

Gould, H. F.

Ludlow Water Co., 185 Devonshire street, Boston, Mass.

Goulds Mfg. Co. The.

"Engines," 236 Congress street, Boston, Mass.

Harlow, Mellen S.

"Pohlé Air Lift Pump," "Ingersoll-Sergeant Drill Co.," 201 Congress street, Boston, Mass.

Hawkins, F. B.

"Cast Iron Pipe," 29 Broadway, New York City.

Helmer, W. K.

Agent Holly Mfg. Co., Lockport, N. Y.

Hersey Manufacturing Co.

"Meters," South Boston, Mass.

Holly Manufacturing Co.

"Pumping Machinery," Lockport, N. Y.

Hydraulic Construction Co., The.

"Well Plants," William D'H. Washington, General Manager, Rooms 46 and 47, 145 Broadway, New York City.

Jackson & Woodin Mfg. Co.

"Cast Iron Pipe," Berwick, Penn.

Jenkins Bros.

"Valves and Packing," 17 Pearl street, Boston, Mass.

Jenks, Henry F.

"Drinking Fountains," Pawtucket, R. I.

Ludlow Valve Mfg. Co.

"Valves and Hydrants," Troy, N. Y.

Lynch, John E.

Proprietor "E. Hodge & Co., Stand Pipes," East Boston, Mass.

McNeal Pipe and Foundry Co., The.

"Cast Iron Pipe," Burlington, N. J.

Michigan Brass and Iron Works.

"Valves, Hydrants and Brass Goods, Detroit. Mich."

Moore, Charles A.

"Engines, Boilers and Supplies." 111 Liberty street, New York City.

Morison, Samuel L.

The Morison-Jewell Filtration Company, 26 So. 15th street, Philadelphia, Penn.

Morris, I. P. Co.

"Pumping Engines," cor. Beach and Ball streets, Philadelphia, Penn.

Mueller, H. Mfg. Co.

"Water Works Supplies," Decatur, Ill.

National Lead Co. (Boston Branch).
234 Congress street, Boston, Mass.

National Meter Co.
"Meters," 118 Chambers street, New York City.

National Tube Works Co.
"Pipe and Fittings," McKeesport, Pa. Address P. W. French, Secretary, 70 Federal street, Boston, Mass.

Neptune Meter Co.
"Trident Water Meters," 253 Broadway, New York City.

New York Filter Co.
"Filters," 145 Broadway, New York City.

Norwood Engineering Co.
"Hydrants, etc.," Florence, Mass.

Nye, Walter B.
"Warren Filter," 220 Devonshire street, Boston, Mass.

Peck Bros & Co.
"Water Works Supplies, 65 Oliver street, Boston; Mass.

Perrin, Seamans & Co.
"Construction Tools and Supplies," 57 Oliver street, Boston, Mass.

Pittsburg Meter Co.
"Water Meters," Pittsburg, Pa.

Ranton, William J.
1300 1st North street, Syracuse, N. Y.

Rensselaer Mfg. Co.
"Valves and Water Gates," Troy, N. Y.

Roberts, C. E.
Hartford Steam Boiler Inspection and Insurance Co., 125 Milk street, Telephone Building, Boston, Mass.

Robertson, R. A.
Treasurer Builders' Iron Foundry, P. O. Box 218, Providence, R. I.

Rose Valve Co.
"Valves," Troy, N. Y.

Ryder, N. F.
"Varnish," Middleboro, Mass.

Sampson, George H.
"Powder," 147 Pearl street, Boston, Mass.

Smith, Anthony P.
"Tapping Machines," 921 Prudential Bldg., Newark, N. J.

Smith, Benjamin C.
"Water Works Supplies," 275 Pearl street, New York City.

Smith, B. F. & Bro.
"Artesian and Driven Wells," 38 Oliver street. Boston, Mass.

Snow, Franklin A.
Civil Engineer and Contractor, 490 Broad street, Providence, R. I.

Snow Steam Pump Co., The.
"Steam Pumps," Buffalo, N. Y.

Star Pipe Jointer Co.
"Pipe Joiners," Quincy, Mass.

Sumner & Goodwin Co.
"Water Works Supplies," 21 Oliver street, Boston, Mass.

Talcott, C. W.
"Contractor," Woonsocket, R. I.

Temby, H. B.
Agent "Repauno Chemical Co.," 13 Broad street, Boston, Mass.

Thomson Meter Co.
"Water Meters," 83 Washington street, Brooklyn, N. Y.

Union Water Meter Co.
"Water Meters," 31 Hermon street, Worcester, Mass.

Waldo Bros.
"Contractors' Supplies," 88 Water street, Boston, Mass.

Walworth Mfg. Co.
"Pipe, Brass Work, Service Boxes, etc.," 16 Oliver street, Boston, Mass.

Wolfendale, Wm.
Agent Plumbers' Supplies, 76 Second street, Fall River, Mass.

Wood, Lester E.

Agt. "Anniston Pipe & Foundry Co." and "Chattanooga Foundry & Pipe Works," 100 Broadway, New York City.

Wood R. D. & Co.

"Cast Iron Pipe," 400 Chestnut street, Philadelphia, Penn.

Woodman Co., The George.

"Pipe and Fittings," 41 Pearl street, Boston, Mass., P. O. Box, 3653.

Worthington, H. R.

"Pumping Engines," Hydraulic Works, South Brooklyn, N. Y.